3.0 CONSERVATION STRATEGY OPTION 1 EVALUATION

Using the methods described in Section 2, this section presents an evaluation of Option 1. Option 1 is evaluated based on how it addresses each of the evaluation criteria and how it performs relative to the other Options and base conditions. While Option 1 as described does not include new facilities, there are a number of facilities that may be necessary to allow Option 1 to achieve BDCP planning and conservation goals. Such facilities as fish screens and new or reinforced levees are mentioned in the discussion of individual criteria where applicable, but for the purposes of the comparative evaluation they are not included as part of Option 1.

3.1 BIOLOGICAL CRITERIA

Option 1 includes operational modifications to the existing SWP and CVP export facilities in the south Delta. Modifications of existing export operations have the potential to reduce aquatic species vulnerability to entrainment at the export facilities as well as to modify hydrodynamic conditions in the Delta that may affect habitat conditions for covered fish species. To accommodate through-Delta water conveyance under Option 1 the primary location of potential physical habitat restoration and enhancement measures is expected to occur in the northern and western reaches of the Delta (e.g., Cache Slough area, Yolo Bypass, and Sutter and Steamboat Sloughs), and in Suisun Marsh (Figure 1-2). Results of the assessment of biological criteria and potential benefits to the covered fish species under Option 1 are described in this section.

The evaluation of biological criteria for Option 1 is based on the hydrodynamic parameter values modeled for operational Scenarios A and B. The evaluation discussions presented below for each species and criterion, however, focus on Scenario A because:

- the type of effects of Scenario B on stressors and stressor impact mechanisms for each of the covered fish species are the same as described for Scenario A and a description of the performance of Scenario B would be repetitious;
- Scenario A would be more likely to achieve water supply objectives than Scenario B and, therefore, comparison of hydrodynamic outputs for scenario A across the Options puts each Option on an equivalent basis; and
- the magnitude of the effects of the Option on covered fish species differs between Scenarios A and B and, consequently, CALSIM II and DSM2 modeling results for Scenario B provided information useful in determining the range of flexibility within the Option to improve performance of the Option relative to achieving each of the biological criteria.

Though not described in the criteria evaluation text, the expected performance of Scenario B on each of the important stressors for each of the covered fish species relative to the performance of Scenario A is presented in summary tables at the beginning of each species evaluation section below.

3.1.1 Delta Smelt

Based on the evaluation presented below of the expected performance of Option 1 for addressing important delta smelt stressors, Option 1 would be expected to have a very low beneficial effect on delta smelt production, distribution, and abundance relative to base conditions when operated to meet water supply objectives (Scenario A). If water supply exports are reduced (Scenario B), Option 1 would be expected to provide a low beneficial effect on delta smelt production, distribution, and abundance relative to base conditions. Option 1 would be expected to provide the lowest benefits for delta smelt compared to the other Options.

Stressors that affect delta smelt are presented in Figures 2-1 and are described in Appendix C. The effect of these stressors on the delta smelt population vary among years in response to environmental conditions (e.g., seasonal hydrology) and may also interact with each other in additive or synergistic ways. The effects of these stressors include both the incremental contribution of a stressor to the population as well as the cumulative effects of multiple stressors over time. The assessment of Option 1 evaluates the degree to which Option 1 would be expected to address these stressors.

Table 3-1 summarizes the expected effects of implementing Option 1 under Scenarios A and B on important delta smelt stressors relative to base conditions.

Table 3-1. Summary of Expected Effects of Option 1 on Highly and Moderately Important Delta Smelt Stressors

Stressors[1]	Applicable Criteria	Option Effects on Important Species Stressors Relative to Base Conditions	
		Scenario A	Scenario B
Highly Important Stressors			
Reduced food availability	1,3,4,5	Very low benefit	Moderate benefit
Reduced rearing habitat	2,3	Very low benefit	Low benefit
Reduced turbidity	1,2,3,5	Very low benefit	Low benefit
Reduced spawning habitat	3	Low benefit	Low benefit
Reduced food quality	1,4,5	Low benefit	Low benefit
Moderately Important Stressors			
Predation	1,5	Low benefit	Low benefit
CVP/SWP entrainment[2]	1	No net effect	Moderate benefit
Exposure to toxics	1,2	No net effect	Very low adverse effect

Notes:

1. See Appendix C for descriptions of stressors, stressor impact mechanisms, and stressor effects.
2. It is recognized that the risk of entrainment at the SWP and CVP export facilities may be a high level stressor to delta smelt in some years and a very low level stressor to delta smelt in other years. For purposes of this analysis, the risk of delta smelt entrainment has been characterized, on average, as a moderate level stressor to the population.

3.1.1.1 Criterion #1. Relative degree to which the Option would reduce species mortality attributable to non-natural mortality sources, in order to enhance production (reproduction, growth, survival), abundance, and distribution for each of the covered fish species.

Important stressors that cause non-natural mortality of delta smelt (see Appendix C) are:

- Reduced food availability,
- Reduced turbidity,
- Reduced food quality,
- Predation,
- Entrainment by CVP/SWP facilities, and
- Exposure to toxics.

Based on the following evaluation of Option 1 effects on applicable delta smelt stressors, Option 1 is expected to provide very low benefits relative to base conditions by reducing the effects of non-natural sources of mortality on delta smelt.

Reduced Food Availability and Quality

Reduced food availability and quality can result in non-natural levels of mortality. The effects of Option 1 on delta smelt food availability and quality are evaluated under Criterion #4 below. As described in the Criterion #4 evaluation, Option 1 would be expected to provide a very low beneficial effect on food availability and a low beneficial effect on food quality for the delta smelt relative to base conditions.

Reduced Turbidity

Reduced turbidity increases the vulnerability of delta smelt to predation. The effects of Option 1 on turbidity are evaluated under Criterion #2 below. As described in the Criterion #2 evaluation, Option 1 would be expected to provide no to very low beneficial increases in turbidity conditions relative to base conditions.

Predation

Predation by non-native species (e.g., striped bass, largemouth bass) on delta smelt can result from at least two impact mechanisms: 1) the establishment of non-native submerged aquatic plants and introduction of man-made structures that provide habitat for non-native predators and 2) reduced turbidity that increases the vulnerability of delta smelt to predation.

As described below under Criterion #2, Option 1 would be expected to have no effect on turbidity conditions relative to base conditions. Although there is a high degree of uncertainty, restoration of high quality aquatic habitat under Option 1 could reduce the vulnerability of delta smelt to predation. Under Option 1, opportunity areas for physical habitat restoration would encompass Suisun Bay and Marsh and approximately 28% of the Delta (in the northern and western portions) to provide high quality aquatic habitat under this Option (Figure 1-2), which encompasses a large segment of the delta smelts range. Benefits associated with this habitat restoration relative to predation vulnerability, however, would be expected to be tempered because turbidity and hydrological conditions (e.g., flow rates at multiple Delta locations; see Appendix D) would not change substantially from base conditions, which currently benefit non-native predators. Consequently, the potential to reduce the impact of non-native predators on delta smelt is expected to very low under Option 1.

Entrainment by CVP/SWP facilities

Operation of the SWP and CVP export facilities results in the entrainment and salvage of delta smelt. Delta smelt entrained into the export facilities are expected to experience increased risk of predation mortality, entrainment through the louvers, and direct loss from the Delta, and increased levels of stress and mortality during collection, handling, transport, and release in fish salvage operations.

The vulnerability of delta smelt to export-related losses varies in response to a number of factors including the geographic distribution of smelt within the estuary, hydrodynamic conditions occurring within the central and southern regions of the Delta (e.g., Old and Middle rivers), and the export rate. Measurements used to assess entrainment risk by the SWP/CVP pumps included (1) hydrodynamic model results of the magnitude of reverse flows in Middle and Old Rivers under each Option and (2) PTM results of CVP/SWP export fate.

Results of these measurements indicate that the hydrodynamics of the Delta and the risk for entrainment of delta smelt would both remain similar to base conditions (see Appendix D and H).

Exposure to Toxics

Exposure of delta smelt to toxic substances can result in mortality of delta smelt. The effects of Option 1 on exposure to toxics are evaluated under Criterion #2 below. As described in the Criterion #2 evaluation, Option 1 would be expected to have a similar risk for exposure to toxics relative to base conditions.

3.1.1.2 Criterion #2. Relative degree to which the Option would provide water quality and flow conditions necessary to enhance production (reproduction, growth, survival) , abundance, and distribution for each of the covered fish species.

Important stressors that affect water quality and flow conditions for delta smelt (see Appendix C) are:

- Reduced rearing habitat,
- Reduced turbidity, and
- Exposure to toxics.

Based on the following evaluation of Option 1 effects on applicable delta smelt stressors, Option 1 is expected to provide very low benefits for water quality and flow conditions that support delta smelt relative to base conditions.

Reduced Rearing Habitat

Reduced rearing habitat for delta smelt can result from at least three impact mechanisms: compression of the estuarine salinity field (X_2), reduced net downstream flows that impede access to rearing habitat, and reduced turbidity that can reduce foraging efficiency of juvenile smelt (see Figure 2-1 and Appendix C). Measurements used to assess effects of Option 1 on rearing habitat included (1) hydrologic model results for the position of X_2 in April, (2) PTM modeling results for particle fate past Chipps Island and particle residence time in the central Delta, (3) Sacramento River flows at Rio Vista, and (4) Delta outflow during March and April, when larval delta smelt are transported downstream.

The location of X_2 affects the location of the low salinity zone, where delta smelt juveniles and adults rear (Bennett 2005). Higher outflows tend to locate X_2 farther downstream, which provides more and better rearing habitat (defined as open water) for delta smelt and makes them less vulnerable to reverse flows in Old and Middle Rivers and, therefore, entrainment. Modeling results for Option 1 show that the change in location of X_2 in April relative to base conditions is 0.5 km upstream (see Appendix H).

Net downstream flows are important for transporting planktonic larval delta smelt towards suitable rearing habitat in the western Delta and Suisun Bay. PTM modeling results indicate that the percentage of particles that moved past Chipps or into Suisun Bay would generally be equal to or marginally greater under Option 1 relative to base conditions, indicating Option 1 would be unlikely to affect downstream movement of larval delta smelt (see Appendices D and H).

Based on PTM modeling results, Option 1 would be expected to maintain turbidity conditions similar to base conditions (see discussion below) and thus would not be expected to affect foraging conditions in rearing habitats.

Modeling results for Sacramento River flows and total Delta outflow indicate that in all water year types larval fish from the Cache Slough/Yolo Bypass area, which is thought to be high quality delta smelt spawning habitat, would be transported downstream to the low salinity zone similar to base conditions. Once these fish are in the Delta, however, there is a moderate beneficial effect on larval transport because flow rates (i.e., Delta Outflow) greatly increase and fish are transported towards the low salinity zone much more effectively than under base conditions (see Appendices D and H).

Reduced Turbidity

Reduced turbidity can result from at least four impact mechanisms: reduction in hydraulic residence time, filtering of organic material from the water column by *Corbula*, filtering of suspended sediments from the water column by non-native aquatic plants (e.g., *Egeria*), and reduction in upstream inputs of sediments from a range of causes. Reduced turbidity reduces foraging efficiency and increases vulnerability of delta smelt to predation (see Appendix C).

Measurements used to assess performance of Option 1 for reducing turbidity included (1) hydrologic model results for peak Delta inflows from January through March, (2) PTM modeling results for hydraulic residence time for the central Delta, and (3) the proportion of the Delta expected to be suitable for restoration of aquatic and intertidal habitat.

There is increased evidence that delta smelt have specific turbidity requirements that can influence their survival and foraging efficiency (Basker-Bridges et al. 2004, POD Action Plan 2007, Feyrer et al. 2007). Results of laboratory studies indicate that, in low turbidity waters, delta smelt move to the edge of aquaria, presumably to reduce vulnerability to predation and reduce feeding. Fullerton (unpubl. data) found that movement patterns of sub-adults suggest that they prefer waters with increased levels of turbidity. One of the primary factors affecting turbidity during winter in the Delta is storm water runoff within the upstream watershed that is carried into the Delta by Delta inflows. Model results indicates that peak Delta inflows during January through March under Option 1 were similar to base conditions on average (see Appendices D and H), indicating that peak flows will not be expected to change turbidity levels under Option 1 relative to base conditions.

Increasing hydraulic residence time increases turbidity by allowing primary producers (phytoplankton) and primary consumers (zooplankton) to increase in the Delta (Feyrer et al. 2007). Generally, residence time under Option 1 would be expected to be highly variable, but on average similar to base conditions.

Non-native clams that filter phytoplankton and zooplankton from the water column (i.e., *Corbula*) and extensive submerged beds of non-native aquatic vegetation (e.g., *Egeria*) can reduce water velocity and increase settling rates of sediments thereby reducing turbidity (Kimmerer and Orsi 1996, Jassby et al. 2002, Kimmerer 2002; Nestor et al. 2003, Hobbs et al. 2006). Under Option 1, habitat could be restored at sites in Suisun Bay and Marsh and approximately 28% of the planning area to provide high quality aquatic habitat under this Option (Figure 1-2). These potential restoration areas under Option 1 encompass a smaller proportion of the delta smelt's range than the proportion of the Delta within which habitat could be restored under the other Options. Therefore, this Option has the lowest potential among the four Options to increase turbidity by reducing the potential effects of non-native species and would be expected to provide a very low beneficial improvement in turbidity.

Exposure to Toxics

Exposure of delta smelt to toxic substances can result from point and non-point sources associated with agricultural, urban, and industrial land uses. There was a reported toxic event in the winter of 2007 that coincided temporally and spatially with delta smelt spawning in the Cache Slough region of the Delta and was also detected further downstream in the lower Sacramento River near Sherman Island (DWR unpubl. data). Additional indications of toxicity have been detected within Suisun Bay during the summer 2007 (S. Ford pers comm.). Although no specific causal link has been established, these toxic events coincided with low abundance indices of larval and juvenile delta smelt observed in the 2007 CDFG 20 mm townet and summer townet surveys. There is little evidence that toxics impact delta smelt directly and, in fact, there is a growing body of evidence that toxics have little direct effect on delta smelt (Bennett, unpubl. data, Werner 2007, Herbold pers. comm., POD Action Plan 2007). There is inconsistent evidence that the invertebrate prey of delta smelt is affected by toxics (Weston et al.

2004, POD Action Plan 2007). Although there is little research to date on the direct or indirect effects of toxics on delta smelt, this stressor is identified as a concern for delta smelt because of large and rapid potential impact on the species should one or more common toxics prove an important stressor.

Differences in dilution flow rates from the Sacramento River and other Delta tributaries relative to base conditions among the Options are one measure of the potential concentrations of toxics and their potential to effect delta smelt. Measurements used to assess the dilution potential of Option 1 included (1) Sacramento River flows at Rio Vista and (2) Delta outflow during March and April, when larval delta smelt are transported downstream. Modeling results indicate that the toxics dilution potential of Option 1 would be similar to base conditions (see Appendices D and H).

3.1.1.3 Criterion #3. Relative degree to which the Option would increase habitat quality, quantity, accessibility, and diversity in order to enhance and sustain production (reproduction, growth, survival), abundance, and distribution; and to improve the resiliency of each of the covered species' populations to environmental change and variable hydrology.

Important stressors that affect delta smelt habitat quality, quantity, accessibility, and diversity (see Appendix C) are:

- Reduced food availability,
- Reduced rearing habitat,
- Reduced turbidity, and
- Reduced spawning habitat.

Within the planning area, delta smelt habitat conditions are governed by hydrodynamic conditions and the extent and quality of habitat within the planning area. Under Option 1, these conditions relative to base conditions would be affected by the conveyance configuration of Option 1 and restoration of physical habitat that could be sited within Suisun Bay and Marsh and within 28% of the planning area in the north and west Delta.

Based on the following evaluation of Option 1 effects on applicable delta smelt stressors, Option 1 is expected to provide low benefits relative to habitat conditions for the delta smelt.

Reduced Food Availability

Habitat conditions can affect the availability and quality of delta smelt food. The effects of Option 1 on delta smelt food availability are evaluated under Criterion #4 below. As described in the Criterion #4 evaluation, Option 1 would be expected to provide a very low beneficial effect on food supply for the delta smelt relative to base conditions.

Reduced Rearing Habitat

Under Option 1, in addition to the flow benefits for rearing habitat conditions described above under Criterion #2, habitat could be restored within Suisun Bay and Marsh and approximately 28% of the Delta to provide high quality shallow aquatic subtidal and intertidal habitat (Figure 1-2), which encompasses a smaller proportion of the delta smelt rearing range than restoration that could be implemented under the other Options. Consequently, relative to base conditions and the other Options, Option 1 would be expected to provide a very low benefit for delta smelt rearing habitat.

Reduced Turbidity

Habitat conditions that support non-native filter feeders and aquatic plants can reduce turbidity. The effects on turbidity associated with these impact mechanisms are evaluated under Criterion #2 above. As described in the Criterion #2 evaluation, restoring habitat under Option 1 would be expected to have very low beneficial effects on turbidity conditions for delta smelt relative to base conditions.

Reduced Spawning Habitat

Spawning habitat for delta smelt is upstream of the low salinity zone. Although spawning has never been observed in nature, it is generally agreed that the location of young delta smelt larvae is not far from where they hatched. This habitat is thought to be in shallow, low salinity upstream areas with sand or gravel substrate available on which to deposit their sticky egg sacs, such as that habitat found on floodplains (Moyle et al. 2004).

The primary impact mechanism believed to affect spawning habitat is the reclamation and channelization of historical intertidal wetlands that has presumably reduced the amount of habitat available for spawning by delta smelt. Under Option 1, habitat could be restored within Suisun Bay and Marsh and approximately 28% of the Delta to provide high quality aquatic habitat under this Option (Figure 1-2). Habitat restoration opportunities under Option 1 encompass a smaller proportion of the likely spawning range of delta smelt than restoration that could be implemented under the other Options. Consequently, relative to the other Options and to the extent that functioning delta smelt spawning habitat can be successfully restored based on current understanding of its habitat requirements, restoration under Option 1 would be expected to provide a low level of benefit (see Appendix H).

3.1.1.4 Criterion# 4. Relative degree to which the Option would increase food quality, quantity, and accessibility (e.g., phytoplankton, zooplankton, macro-invertebrates, forage fish) to enhance production (reproduction, growth, survival) and abundance for each of the covered fish species.

Important stressors that affect delta smelt food quality, quantity, and accessibility (see Appendix C) are:

- reduced food availability, and
- reduced food quality.

Based on the following evaluation of Option 1 effects on applicable delta smelt stressors, Option 1 is expected to provide very low benefits relative to food quality, quantity, and accessibility for the delta smelt.

Reduced Food Availability

Reduced food availability for delta smelt can result from at least five impact mechanisms: competition with non-native species, reduced frequency of floodplain inundation, nutrient and food exports from CVP/SWP pumps and in-Delta agricultural diversions, hydraulic residence time, and effects of toxics (e.g., pesticides/herbicides) on zooplankton abundance (see Figure 2-1 and Appendix C). Measurements used to assess effects on food availability included (1) PTM modeling results for CVP/SWP for particle fate in the central Delta, (2) change in peak total Delta inflows from January through March, and (3) the proportion of the Delta expected to be suitable for restoration of aquatic and intertidal habitat.

Restoration of tidal and intertidal habitats could create conditions that disfavor non-native species that indirectly or directly affect food abundance (e.g., *Corbula* and threadfin shad), thereby improving food availability for delta smelt. Under Option 1, habitat could be restored within Suisun Bay and Marsh and approximately 28% of the Delta to provide high quality aquatic habitat (Figure 1-2). This is a smaller proportion of the delta smelt range than restoration that could be implemented under the other Options. Delta smelt abundance in recent years, however, has been greatest in the lower Sacramento River near Decker Island, the Cache Slough region, and within Suisun Bay and Marsh (DFG 2007), all of which are within the potential habitat restoration area of Option 1. Because the overall hydrologic conditions (e.g., flow rates at multiple locations; see Appendix D) do not differ substantially from base conditions in most water years (conditions which are believed to favor competitor species), the effect of restoring habitat on reducing competition may be limited. Consequently, the potential benefits for reducing competition to increase food availability for delta smelt under Option 1 are considered low.

Floodplains are highly productive and are thought to be a source of high amounts of allochthonous nutrient and organic carbon production from the terrestrial community that inhabits the floodplain and upland areas during the remainder of the year (Sommer et al. 2001, Harrell and Sommer 2003). One of the major floodplains in the Delta, the Yolo Bypass, floods during approximately 60% of years (Harrell and Sommer 2003). The magnitude of peak flows from January through March, the period during which inflows have been greatest into the Delta historically, gives an indication of the potential for floodplain inundation relative to base conditions. Modeled peak Delta inflows under Option 1 during January through March are nearly identical to base conditions (see Appendix H). Therefore, relative to base conditions, Option 1 would not be expected to provide increased organic material and nutrients from floodplains and transported downstream into the Delta.

The SWP and CVP pumps and the over 2,200 in-Delta agricultural diversions (Herren and Kawasaki 2001) export zooplankton, nutrients, and organic material that would otherwise support the base of the food web in the Delta, thus affecting food availability for the delta smelt (Jassby et al. 2002, POD Action Plan 2007). Based on PTM modeling results for exported particles, the removal of food organisms, nutrients, and organics by diversions is lower relative to base conditions (see Appendices D and H). However, the benefit to delta smelt is expected to be very low because the magnitude of the reduction is relatively low.

The co-occurrence of suitable food supplies (zooplankton) and various life stages of delta smelt (e.g., larval and juvenile life stages) has been identified as an important factor affecting delta smelt survival and abundance (Feyrer et al. 2007, Miller 2007). Reduced hydrologic residence time is thought to reduce productivity in the Delta because nutrients and organics are transported downstream and out of the Delta before stimulating phytoplankton or zooplankton production (Jassby et al. 2002, Kimmerer 2002a,b, POD Action Plan 2007). Increased hydrologic residence time allows more time for bacterial activity to use nutrients and organic carbon and for the production of phytoplankton and zooplankton that provide food for delta smelt and other aquatic species. Based on PTM modeling results, the hydrologic residence time within the Delta varies with both the insertion location and the amount of water entering the system (i.e., exceedance percentage). Overall, residence time within the central Delta under Option 1 would be highly variable but on average would be similar to base conditions (see Appendices D and H). Consequently, the effect of Option 1 on food production is expected to be similar to base conditions. In addition to hydraulic residence time within the Central Delta, results of the PTM showed a similar pattern of particle movement downstream into Suisun Bay where phytoplankton and zooplankton production co-occurs with delta smelt.

It has been hypothesized that exposure of phytoplankton and zooplankton to toxics (e.g., pesticides, herbicides) that enter the Delta from point and non-point sources may also contribute to ongoing low abundance of delta smelt zooplankton prey species (Weston et al. 2004, Luoma 2007). Though this relationship is uncertain, Option 1 would be unlikely to reduce the exposure of primary and secondary producers to these toxics because dilution flows would remain similar to base conditions.

Reduced Food Quality

Low food quality for delta smelt can result from the displacement of native zooplankton species by less nutritious non-native species (see Figure 2-1 and Appendix C). The measurement used to assess the likely effects of Option 1 on food quality was the proportion of the Delta expected to be suitable for restoration of aquatic and intertidal habitat.

The zooplankton community inhabiting the Delta has been affected by a number of factors including the introduction of a number on non-native zooplankton species. These changes in the zooplankton species composition have affected the quality of food resources available to delta smelt since many of the introduced zooplankton species do not appear to be as suitable a food resource as the native species (POD Action Plan 2007). For example, *Limnoithona tetraspina* is a non-native copepod that is smaller and faster than native forage species of zooplankton and is protected by spines (Orsi and Ohtsuka 1999). In the presence of *Limnoithona tetraspina* foraging efficiency of delta smelt has decreased (POD Action Plan 2007; B. Herbold pers comm.).

Restoration of shallow water tidal and subtidal habitats under Option 1 could improve nutrient production and production of suitable zooplankton species (e.g., native calanoid copepods) as forage for delta smelt. Under Option 1, habitat could be restored within Suisun Bay and Marsh and approximately 28% of the Delta to provide high quality aquatic habitat under this Option

(Figure 1-2), which encompasses a smaller proportion of the delta smelt's range than restoration that could be implemented under the other Options. Consequently, relative to the other Options, Option 1 would be expected to provide a low level of benefit for food quality (see Appendix H).

3.1.1.5 Criterion #5. Relative degree to which the Option would reduce the abundance of non-native competitors and predators to increase native species production (reproduction, growth, survival), abundance and distribution for each of the covered fish species.

Non-native competitors and predators are an impact mechanism for the following important delta smelt stressors (see Appendix C):

- Reduced food availability,
- Reduced turbidity,
- Reduced food quality, and
- Predation.

Option 1 is expected to provide low benefits for the delta smelt relative to the abundance of non-native competitors and predators. For reasons described under Criterion #4, Option 1 would be expected to provide a very low beneficial effect by reducing the impacts of populations of non-native food competitors and predators relative to base conditions. For reasons described under Criteria #1 and #2, Option 1 could provide a low beneficial effect by reducing the risk of delta smelt predation relative to base conditions.

3.1.1.6 Criterion #6. Relative degree to which the Option improves ecosystem processes in the BDCP planning area to support aquatic and associated habitats.

Measurements used to assess the potential for Option 1 to improve ecosystem processes included (1) PTM modeling results for hydraulic residence time in the central Delta and (2) the proportion of the Delta expected to be suitable for restoration of aquatic and intertidal habitat. Based on the proportion of the planning area suitable for restoration under Option 1 relative to the other Options and modeling results for hydraulic residence time (see Appendix H), Option 1 would be expected to provide a very low beneficial improvement in ecosystem function relative to base conditions because habitat restoration under Option 1 would improve ecosystem processes, hydraulic residence time would be similar to base conditions. Under Option 1, Delta channels would continue to serve as the water conveyance facilities for freshwater supplies moving from the Sacramento River across the Delta to the export facilities in the south Delta. Movement of large volumes of water through these channels would adversely affect hydraulic conditions within the Delta (e.g., reverse flows), affect salinity levels and distribution, require riprapped levees to reduce erosion and levee scour, and limit the opportunities for habitat enhancement. The hydraulic conditions within the Delta under these operations would continue to reduce hydraulic residence times and export nutrients, organic carbon, phytoplankton, and zooplankton from the Delta resulting in adverse effects on aquatic food production and availability.

3.1.1.7 Criterion #7. Relative degree to which the Option can be implemented within a timeframe to meet the near-term needs of each covered fish species (post BDCP authorization).

Habitat restoration under Option 1 can be initiated immediately following authorization of the BDCP and thus could be implemented in a manner that would meet the near term needs of delta smelt. The expected period for initiating implementation of Option 1 is the same as the other Options.

3.1.2 Longfin Smelt

Based on the evaluation presented below of the expected performance of Option 1 for addressing important longfin smelt stressors, Option 1 would be expected to have a very low beneficial effect on longfin smelt production, distribution, and abundance relative to base conditions when operated to meet water supply objectives (Scenario A). If water supply exports are reduced (Scenario B), Option 1 would be expected to provide a low beneficial effect on longfin smelt production, distribution, and abundance relative to base conditions. Option 1 would be expected to provide the lowest benefits for longfin smelt compared to the other Options.

Stressors that affect longfin smelt are presented in Figures 2-2 and are described in Appendix C. The effect of these stressors on the longfin smelt population vary among years in response to environmental conditions (e.g., seasonal hydrology) and may also interact with each other in additive or synergistic ways. The effects of these stressors include both the incremental contribution of a stressor to the population as well as the cumulative effects of multiple stressors over time. The assessment of Option 1 evaluates the degree to which Option 1 would be expected to address these stressors.

Table 3-2 summarizes the expected effects of implementing Option 1 under Scenarios A and B on important longfin smelt stressors relative to base conditions.

Table 3-2. Summary of Expected Effects of Option 1 on Highly and Moderately Important Longfin Smelt Stressors

Stressors[1]	Applicable Criteria	Option Effects on Important Species Stressors Relative to Base Conditions	
		Scenario A	Scenario A
Highly Important Stressors			
Reduced access to spawning habitat	2	No net effect	Moderate benefit
Reduced access to rearing habitat	2	No net effect	Moderate benefit
Reduced food	1,4,5	Very low benefit	Moderate benefit
Predation	1,5	Low benefit	Low benefit
Reduced turbidity	1,2, 3,5	Very low benefit	Low benefit
Reduced spawning habitat	3	Very low benefit	Very low benefit
Reduced food quality	1,4,5	Very low benefit	Very low benefit

Table 3-2. Summary of Expected Effects of Option 1 on Highly and Moderately Important Longfin Smelt Stressors (continued)

Stressors[1]	Applicable Criteria	Option Effects on Important Species Stressors Relative to Base Conditions	
		Scenario A	Scenario A
Moderately Important Stressors			
CVP/SWP entrainment[2]	1	No net effect	Moderate benefit
Reduced rearing habitat	2	No net effect	Moderate benefit
Exposure to toxics	2	No net effect	Low adverse effect

Notes:

1. See Appendix C for descriptions of stressors, stressor impact mechanisms, and stressor effects.
2. It is recognized that the risk of entrainment at the SWP and CVP export facilities may be a high level stressor to longfin smelt in some years and a very low level stressor to longfin smelt in other years. For purposes of this analysis, the risk of delta smelt entrainment has been characterized, on average, as a moderate level stressor to the population.

3.1.2.1 Criterion #1. Relative degree to which the Option would reduce species mortality attributable to non-natural mortality sources, in order to enhance production (reproduction, growth, survival), abundance, and distribution for each of the covered fish species.

Important stressors that cause non-natural mortality of longfin smelt (see Appendix C) are:

- Reduced food availability,
- Predation,
- Entrainment by CVP/SWP facilities,
- Reduced turbidity,
- Reduced food quality,
- Predation, and
- Exposure to toxics.

Based on the following evaluation of Option 1 effects on applicable longfin smelt stressors, Option 1 is expected to provide very low benefits relative to base conditions by reducing the effects of non-natural sources of mortality on longfin smelt.

Reduced Food Availability and Quality

Reduced food availability and quality can result in non-natural levels of mortality. The effects of Option 1 on longfin smelt food availability and quality are evaluated under Criterion #4 below.

As described in the Criterion #4 evaluation, Option 1 would be expected to provide a very low beneficial effect on food availability and quality for longfin smelt relative to base conditions.

Reduced Turbidity

Reduced turbidity may increase the vulnerability of longfin smelt to predation and reduce foraging efficiency. The effects of Option 1 on turbidity are evaluated under Criterion #2 below. As described in the Criterion #2 evaluation, Option 1 would be expected to provide very low beneficial increases in turbidity conditions relative to base conditions.

Predation

The primary impact mechanism for predation by non-native species (e.g., sunfish, largemouth bass) on longfin smelt are non-native submerged aquatic plants throughout the planning area that provide habitat for non-native predators and reduced turbidity which can increase the vulnerability of longfin smelt to predation. Although there is a high degree of uncertainty, restoration of high quality aquatic habitat under Option 1 could reduce the vulnerability of longfin smelt to predation. Under Option 1, habitat could be restored within Suisun Bay and Marsh and approximately 28% of the Delta to provide high quality aquatic habitat under this option (Figure 1-2). Benefits associated with this habitat restoration relative to predation vulnerability, however, would be expected to be tempered because hydrodynamic conditions (e.g., flow rates at multiple Delta locations; see Appendix D) would not change substantially from base conditions, which currently benefit non-native predators. Consequently, the potential to reduce the impact of non-native predators on longfin smelt is expected to low under Option 1.

Entrainment by CVP/SWP facilities

Operation of the SWP and CVP export facilities results in the entrainment and salvage of longfin smelt. Longfin smelt entrained into the export facilities are expected to experience increased risk of predation mortality, entrainment through the louvers, direct loss from the Delta, and increased levels of stress and mortality during collection, handling, transport, and release from the fish salvage operations.

The vulnerability of longfin smelt to export-related losses varies in response to a number of factors including the geographic distribution of smelt within the estuary, hydrodynamic conditions occurring within the central and southern regions of the Delta (e.g., the magnitude of reverse flows within Old and Middle rivers), and the export rate. Measurements used to assess entrainment risk by the SWP/CVP pumps included (1) hydrodynamic model results of the magnitude of reverse flows in Middle and Old rivers under each Option, (2) PTM results of CVP/SWP export fate, and (3) index of vulnerability for longfin smelt to salvage at the export facilities.

Results of these measurements indicate that the hydrodynamics of the Delta would remain similar to base conditions and that the risk for entrainment of longfin smelt would remain similar to base conditions (see Appendix D and H).

Exposure to Toxics

Exposure of longfin smelt to toxic substances can result in mortality of longfin smelt. The effects of Option 1 on exposure to toxics are evaluated under Criterion #2 below. As described in the Criterion #2 evaluation, Option 1 would be expected to have a similar risk for exposure to toxics relative to base conditions.

3.1.2.2 Criterion #2. Relative degree to which the Option would provide water quality and flow conditions necessary to enhance production (reproduction, growth, survival), abundance, and distribution for each of the covered fish species.

Important stressors that affect water quality and flow conditions for longfin smelt (see Appendix C) are:

- Reduced access to spawning habitat
- Reduced access to rearing habitat,
- Reduced turbidity, and
- Exposure to toxics.

Based on the following evaluation of Option 1 effects on applicable longfin smelt stressors, Option 1 is expected to provide very low benefits for water quality and flow conditions that support longfin smelt relative to base conditions.

Reduced Access to Spawning Habitat

Higher Delta outflows tend to locate X_2 further downstream within Suisun Bay, which is thought to increase the quantity and quality of estuarine rearing habitat (defined as open water) for longfin smelt and makes them less vulnerable to reverse flows on Old and Middle rivers and, therefore, entrainment. Conversely, lower Delta outflows tend to push X_2 farther upstream. Results of analyses of CDFG fishery survey data have shown a relationship between X_2 location and indices of longfin smelt abundance (Swanson et. Al. 2007). Modeling results for Option 1 show that the change in location of X_2 in April relative to base conditions is 0.5 km upstream (see Appendices D and H). The potential changes in access to spawning habitat for adult longfin smelt, based on winter and spring flows are expected to be similar under Option 1 as base conditions.

Reduced Access to Rearing Habitat

Reduced access to rearing habitat for longfin smelt can result from low net downstream flows that impede the transport of longfin smelt to rearing habitat (see Figures 2-2 and Appendix C). Measurements used to assess effects of Option 1 on access to rearing habitat included (1) PTM modeling results for particle fate past Chipps Island and particle residence time in the central Delta, (2) Sacramento River flows at Rio Vista and (3) Delta outflow during March and April, when larval longfin smelt are transported downstream.

Net downstream flows are important for transporting planktonic larval longfin smelt downstream towards suitable rearing habitat in the western Delta and Suisun Bay. PTM modeling results indicate that the percentage of particles that moved past Chipps Island or into Suisun Bay would generally be equal to or marginally greater under Option 1 relative to base conditions, indicating Option 1 would be unlikely to affect downstream movement of larval longfin smelt (see Appendices D and H).

Modeling results for Sacramento River flows and total Delta outflow indicate that in all water year types larval fish from the Cache Slough/Yolo Bypass area, which is thought to be high quality longfin smelt spawning habitat, will be transported downstream to the low salinity zone similarly to base conditions. Once these fish are in the Delta, flow rates (i.e., Delta Outflow and the influence of tidal flows) greatly increase and fish are transported towards the low salinity zone rearing habitats much more effectively than under base conditions (see Appendices D and H) which is expected to benefit larval and early juvenile longfin smelt by improved rearing conditions.

Reduced Turbidity

Reduced turbidity can result from at least four impact mechanisms: reduction in hydraulic residence time, filtering of organic material from the water column by *Corbula* and other benthic and pelagic species, filtering of suspended sediments from the water column by non-native aquatic plants (e.g., *Egeria*), and reduction in upstream inputs of sediments resulting from upstream water management and reservoir storage that reduce sediment flow and attenuate peak flows into the Delta (Kimmerer and Orsi 1996, Jassby et al. 2002, Nestor et al. 2003, Kimmerer 2000a,b, 2004, Feyrer et al. 2007, POD Action Plan 2007). Levee construction and river channelization have also affected sediment scour and erosion within the watershed. Measurements used to assess performance of Option 1 for reducing turbidity included (1) hydrologic model results of peak Delta inflows from January through March, (2) PTM modeling results for hydraulic residence time for the central Delta, and (3) the proportion of the Delta expected to be potentially suitable for restoration of aquatic subtidal and intertidal habitat.

There is growing evidence that longfin smelt have specific turbidity requirements that may influence their ability to forage and avoid predation (Basker-Bridges et al. 2004, S. Foote unpubl. data, R. Baxter pers. comm.). Turbidity has decreased over the past several decades in the Delta as a result of a variety of factors. Increasing currently low turbidity levels in the Delta may reduce the vulnerability of longfin smelt to predation and increase longfin smelt foraging efficiency.

Model results indicate that peak Delta inflows during January through March under Option 1 were similar to base conditions on average (see Appendices D and H), indicating that peak flows will not be expected to change turbidity levels under Option 1 relative to base conditions.

Increasing hydraulic residence time increases turbidity by allowing primary producers (phytoplankton) and primary consumers (zooplankton) to bloom in the Delta when conditions are favorable (Feyrer et al. 2007). Generally, residence time under Option 1 would be expected to be highly variable, but on average similar to base conditions.

Non-native clams that filter phytoplankton and zooplankton from the water column (i.e., *Corbula*) and extensive submerged beds of non-native aquatic vegetation (e.g., *Egeria*, water hyacinth) can reduce water velocity and increase settling rates of sediments thereby reducing turbidity (Kimmerer and Orsi 1996, Jassby et al. 2002, Kimmerer 2002; Nestor et al. 2003, Hobbs et al. 2006). Restoration of aquatic subtidal and intertidal habitats could occur over approximately 28% of Delta (Figure 1-2), which provides the smallest proportion of the Delta within which habitat can be restored among the Options. Therefore, this Option has the lowest potential among the four Options to increase turbidity by reducing the potential effects of non-native species and would be expected to provide a very low beneficial improvement in turbidity conditions for longfin smelt.

Exposure to Toxics

Exposure of longfin smelt to toxic substances can result from point and non-point sources associated with agricultural, urban, and industrial land uses. Longfin smelt would potentially be exposed to these toxic materials during their period of residence within the Delta. As with delta smelt (see Section 3.1.1), there is little evidence that toxics impact longfin smelt directly (S. Footte unpubl. data, R. Baxter pers comm., POD Action Plan 2007). Further, there is inconsistent evidence that the invertebrate prey of longfin smelt is affected by toxics. However, this stressor is still identified as a concern for longfin smelt. Chronic exposure of longfin smelt to toxics may be more of a concern than for delta smelt because they are slightly longer-lived (2-3 years) and can, therefore, potentially bioaccumulate toxics to higher levels.

Dilution flows from the Sacramento River and other Delta tributaries are one way of reducing concentrations of toxics and their effect on longfin smelt. Measurements used to assess the dilution potential of Option 1 included (1) Sacramento River flows at Rio Vista and (2) Delta outflow during March and April, when larval longfin smelt are transported downstream. Modeling results indicate that the toxics dilution potential of Option 1 would be similar to base conditions (see Appendices D and H).

Reduced Rearing Habitat

Reduced rearing habitat for longfin smelt can result from compression of the estuarine salinity field (X_2), which is measured using the hydrodynamic modeling results for the position of X_2 in April.

Rearing habitat of longfin smelt is thought to be located in and downstream of the low salinity zone in open waters (Baxter 1999, Moyle 2002). When the low salinity zone is located upstream during periods of low Delta outflow, particularly upstream of the confluence between the Sacramento and San Joaquin rivers, the quantity and quality of rearing habitat may be reduced. Modeling results indicate that in April X_2 would be located 0.5 km farther upstream relative to base conditions. As described below, Option 2 would be expected to provide no improvement in turbidity conditions relative to base conditions and therefore would not be expected to improve the foraging efficiency of longfin smelt or reduce their vulnerability to predation. Consequently, overall Option 1 would be expected to have no benefits to rearing habitat conditions relative to base conditions.

3.1.2.3 Criterion# 3. Relative degree to which the Option would increase habitat quality, quantity, accessibility, and diversity in order to enhance and sustain production (reproduction, growth, survival), abundance, and distribution; and to improve the resiliency of each of the covered species' populations to environmental change and variable hydrology.

Important stressors that affect longfin smelt habitat quality, quantity, accessibility, and diversity (see Figure 2-2 and Appendix C) are:

- Reduced access to spawning habitat,
- Reduced access to rearing habitat,
- Reduced food availability
- Reduced turbidity,
- Reduced spawning habitat
- Reduced rearing habitat.

Within the planning area, longfin smelt habitat conditions are governed by hydrodynamic conditions and the extent and quality of habitat within the planning area. Under Option 1, these conditions relative to base conditions would be affected by the conveyance configuration of Option 1 and the opportunities for restoration of physical habitat that could be sited within Suisun Bay and Marsh and within the planning area in the north and west Delta, which represents approximately 28% of the planning area.

Based on the following evaluation of Option 1 effects on applicable longfin smelt stressors, Option 1 is expected to provide very low benefits relative to habitat conditions for the longfin smelt.

Reduced Accessibility to Spawning and Rearing Habitats

The effects of Option 1 on the accessibility of spawning and rearing habitats are evaluated under Criterion #2 above. As described in the Criterion #2 evaluation, Option 1 would not be expected to affect longfin smelt access to spawning and rearing habitats relative to base conditions.

Reduced Food Availability and Quality

Reduced food availability and quality can result in non-natural levels of mortality. The effects of Option 1 on longfin smelt food availability and quality are evaluated under Criterion #4 below. As described in the Criterion #4 evaluation, Option 1 would be expected to provide a very low beneficial effect on food availability and quality for longfin smelt relative to base conditions.

Reduced Turbidity

Habitat conditions that support non-native filter feeders and aquatic plants can reduce turbidity. The effects on turbidity associated with these impact mechanisms are evaluated under Criterion #2 above. As described in the Criterion #2 evaluation, restoring habitat under Option 1 would be expected to have a very low beneficial effect on turbidity conditions for longfin smelt relative to base conditions.

Reduced Spawning Habitat

Spawning habitat for longfin smelt is believed to be located in the main river channels upstream of the low salinity zone. The primary impact mechanism believed to affect spawning habitat is the reclamation and channelization of historical intertidal wetlands that has presumably reduced the amount of habitat available for spawning by longfin smelt. Under Option 1 approximately 28% of the planning area would be available for restoration/enhancement of aquatic subtidal and intertidal habitats (Figure 1-2), which encompasses most of the geographic range of longfin smelt within the Delta (Rosenfield and Baxter, in press). Because turbidity conditions would remain similar to base conditions (which affects predation vulnerability and foraging efficiency), habitat restoration under Option 1 would likely provide a very low benefit to longfin smelt.

Reduced Rearing Habitat

The effects on rearing habitat associated with Option 1 are evaluated under Criterion #2 above. Option 1 is expected to have no net effect on the transport of longfin smelt larvae to downstream rearing habitats relative to base conditions.

3.1.2.4 Criterion #4. Relative degree to which the Option would increase food quality, quantity, and accessibility (e.g., phytoplankton, zooplankton, macro-invertebrates, forage fish) to enhance production (reproduction, growth, survival) and abundance for each of the covered fish species.

Important stressors that affect longfin smelt food quality, quantity, and accessibility (see Figure 2-2 and Appendix C) are:

- Reduced food availability and
- Reduced food quality.

Based on the following evaluation of Option 1 effects on applicable longfin smelt stressors, Option 1 is expected to provide very low benefits relative to food quality, quantity, and accessibility for the longfin smelt.

Reduced Food Availability

Reduced food availability for longfin smelt can result from at least five impact mechanisms: competition with non-native species, reduced frequency of floodplain inundation, nutrient and food exports from CVP/SWP pumps and in-Delta agricultural diversions, hydraulic residence time, and effects of toxics (e.g., pesticides/herbicides) on phytoplankton and zooplankton abundance (see Figure 2-2 and Appendix C). Measurements used to assess effects on food availability included (1) PTM modeling results for CVP/SWP for particle fate, (2) change in peak total Delta inflows from January through March, and (3) the proportion of the Delta expected to be suitable for restoration of aquatic subtidal and intertidal habitat.

Restoration of subtidal and intertidal habitats could create conditions that disfavor non-native species that indirectly or directly affect food abundance, thereby improving food availability for longfin smelt. For example, the highly efficient filter-feeding clam, *Corbula amurensis*, consumes zooplankton that would otherwise be available to longfin smelt (Kimmerer and Orsi 1996, Sweetnam 1999, Jassby et al. 2002, Kimmerer et al. 2002a, Hobbs et al. 2006). Approximately 28% of the Delta could potentially be enhanced to provide high quality aquatic habitat under this option (Figure 1-2), which would primarily be located within the northern region of the Delta and the Suisun Bay and Marsh. The brackish water area within Suisun Bay (Figure 1-2) is the area of the estuary most likely to be inhabited by the overbite clam, *Corbula*. Habitat restoration and enhancement also has the potential to increase production of nutrients, organic carbon, phytoplankton, and zooplankton, however, the biological response of native and non-native species to large-scale habitat improvement within the Delta remains uncertain. However, because the overall hydrologic conditions (e.g., flow rates at multiple locations; see Appendix D) do not differ substantially from base conditions in most water years (conditions which are believed to favor competitor species), the effect of restoring habitat on reducing food competition may be limited. Consequently, the potential benefits for reducing competition to increase food availability for longfin smelt under Option 1 are considered very low.

Floodplains are highly productive and are thought to be a source of high amounts of allochthonous nutrients and organic carbon production from the terrestrial community that inhabit the floodplain and upland areas during the remainder of the year (Sommer et al. 2001, Harrell and Sommer 2003). The magnitude of peak flows from January through March, the period during which inflows have been greatest into the Delta historically, gives an indication of the potential for floodplain inundation relative to base conditions. Modeled peak Delta inflows under Option 1 during January through March are similar to base conditions (see Appendix H). Therefore, relative to base conditions, Option 1 would not be expected to provide increased mobilization of organic material and nutrients from floodplains that would then be transported downstream into the Delta.

In addition to removing water from the Delta, SWP/CVP pumps and the over 2,200 in-Delta agricultural diversions (Herren & Kawasaki 2001) can export phytoplankton, zooplankton, nutrients, and organic material (Jassby et al. 2002, POD Action Plan 2007) that would otherwise support the base of the food web from the Delta, and thus could affect food availability for the longfin smelt. Based on PTM modeling results for exported particles, the removal of food organisms, nutrients, and organics by diversions is lower relative to base conditions (see Appendices D and H). However, the benefit to longfin smelt is expected to be very low because the magnitude of the reduction is relatively low.

Reduced hydrologic residence time is thought to reduce productivity in the Delta because nutrients and organics are transported downstream and out of the Delta before stimulating phytoplankton or zooplankton production (Jassby et al. 2002, Kimmerer 2002a,b, POD Action Plan 2007). Increased hydrologic residence time allows more time for bacterial activity to use nutrients and organic carbon and for the production of phytoplankton and zooplankton that provide food for longfin smelt and other aquatic species. Based on PTM modeling results, the hydrologic residence time within the Delta varies with both the insertion location and the amount of water entering the system (i.e., exceedance percentage). Overall, residence time within the central Delta under Option 1 was highly variable but on average similar to base conditions (sees Appendices D and H). Consequently, the effect of Option 1 on food production is expected to be similar to base conditions. In addition to hydraulic residence time within the central Delta, results of the PTM showed a similar pattern of particle movement downstream into Suisun Bay where phytoplankton and zooplankton production co-occurs with longfin smelt.

It has been hypothesized that exposure of phytoplankton and zooplankton to toxics (e.g., pesticides, herbicides) that enter the Delta from point and non-point sources may also contribute to ongoing low abundance of longfin smelt zooplankton prey species (Weston et al. 2004, Luoma 2007). Though this relationship is uncertain, Option 1 would be unlikely to reduce the exposure of primary and secondary producers to these toxics because dilution flows would remain similar to base conditions.

Reduced Food Quality

Reduced food quality for longfin smelt can result from the displacement of native species of zooplankton species with less nutritious non-native species (see Figure 2-2 and Appendix C). The measurement used to assess likely effects of Option 1 on food quality was the proportion of the Delta expected to be suitable for restoration of aquatic subtidal and intertidal habitat.

The zooplankton community inhabiting the Delta has been affected by a number of factors including the introduction of a number on non-native zooplankton species. These changes in the zooplankton species composition have affected the quality of food resources available to longfin smelt since many of the introduced zooplankton species do not appear to be as suitable a food resource as the native species (POD Action Plan 2007). For example, the non-native copepod *Limnoithona tetraspina* (Orsi and Ohtsuka 1999) is described as lower quality prey for longfin smelt because they are small, spiny and have sufficient swimming ability to avoid capture (POD Action Plan 2007, Orsi and Ohtsuka 1999, B. Herbold pers. comm.). As a result, foraging efficiency of longfin smelt has decreased (POD Action Plan 2007).

Restoration of shallow water subtidal and intertidal habitats under Option 1 could improve nutrient production and production of suitable zooplankton species (e.g., native calanoid copepods) as forage for longfin smelt. Under Option 1, habitat could be restored within Suisun Bay and Marsh and approximately 28% of the Delta to provide high quality aquatic habitat under this option (Figure 1-2), which encompasses a smaller proportion of the longfin smelt's range than the proportion of the Delta within which habitat could be restored under the other Options. Consequently, relative to the other Options, Option 1 would be expected to provide a low level of benefit for longfin smelt food quality (see Appendix H).

3.1.2.5 Criterion #5. Relative degree to which the Option would reduce the abundance of non-native competitors and predators to increase native species production (reproduction, growth, survival), abundance and distribution for each of the covered fish species.

Non-native competitors and predators are an impact mechanism for the following important longfin smelt stressors (see Appendix C):

- Reduced food availability
- Reduced turbidity,
- Reduced food quality, and
- Increased predation.

Based on the following evaluation of Option 1 effects on applicable longfin smelt stressors, Option 1 is expected to provide low benefits for the longfin smelt relative to the abundance of non-native competitors and predators.

For reasons described under Criterion #4, Option 1 would be expected to provide a very low beneficial effect by reducing the adverse impacts of populations of non-native food competitors and predators relative to base conditions.

3.1.2.6 Criterion #6. Relative degree to which the Option improves ecosystem processes in the BDCP planning area to support aquatic and associated habitats.

Based on the proportion of the planning area suitable for potential restoration under Option 1 relative to the other Options and modeling results for hydraulic residence time (see Appendix H), Option 1 would be expected to provide a very low beneficial improvement in ecosystem function relative to base conditions.

Measurements used to assess the potential for Option 1 to improve ecosystem processes included (1) PTM modeling results for hydraulic residence time in the central Delta and (2) the proportion of the Delta expected to be suitable for restoration of aquatic and intertidal habitat. Based on the proportion of the planning area suitable for restoration under Option 1 relative to the other Options and modeling results for hydraulic residence time (see Appendix H), Option 1 would be expected to provide a very low beneficial improvement in ecosystem function relative to base conditions because habitat restoration under Option 1 would improve ecosystem processes, hydraulic residence time would be similar to base conditions. Under Option 1, Delta channels would continue to serve as the water conveyance facilities for freshwater supplies moving from the Sacramento River across the Delta to the export facilities in the south Delta. Movement of large volumes of water through these channels would adversely affect hydraulic conditions within the Delta (e.g., reverse flows), affect salinity levels and distribution, require riprapped levees to reduce erosion and levee scour, and limit the opportunities for habitat enhancement. The hydraulic conditions within the Delta under these operations would continue to reduce hydraulic residence times and export nutrients, organic carbon, phytoplankton, and zooplankton from the Delta resulting in adverse effects on aquatic food production and availability.

3.1.2.7 Criterion #7. Relative degree to which the Option can be implemented within a timeframe to meet the near-term needs of each covered fish species (post BDCP authorization).

Habitat restoration under Option 1 can be initiated immediately following authorization of the BDCP and thus could be implemented in a manner that would meet the near-term needs of longfin smelt.

3.1.3 Sacramento River Salmonids[1]

This analysis focuses only on stressors affecting juvenile and adult life stages of Sacramento River salmonids during their migration through the Delta (Figure XX, Appendix C). The Sacramento River supports populations of winter-run, spring-run, fall-run, and late fall-run Chinook salmon, as well as Central Valley steelhead. The majority of juvenile salmonid rearing occurs either within the coastal ocean waters or in tributaries upstream of the Delta (Williams 2006). Juvenile salmonids (fry) may migrate downstream and rear within the Delta for multiple months (Williams 2006), with the greatest numbers typically occurring within the Delta during high-flow years. Juvenile salmonids that rear within upstream river habitats migrate downstream through the Delta as larger juvenile smolts and are thought to inhabit the Delta for a relatively short period of time (weeks, VAMP 2006). Neither Chinook salmon nor steelhead spawn within the Delta, but rather inhabit upstream river habitat for spawning, egg incubation, and juvenile rearing (Williams 2006). Although spawning and most juvenile rearing occurs upstream of the Delta, hydrologic conditions and SWP and CVP facilities operations can potentially affect upstream migration and cold water pool storage in upstream reservoirs. The early life stages of both salmon and steelhead (e.g., incubating eggs and rearing juveniles) are particularly sensitive to exposure to elevated water temperatures (Sullivan et al. 2000). Therefore, the potential for depletion of cold-water storage within SWP and CVP reservoirs located within the Sacramento River watershed compared to base conditions was included as an evaluation metric for this analysis.

It was assumed for purposes of these analyses that the effects of the Options on adult harvest by recreational anglers, such as changes in regulations or enforcement, would apply equally to all Options and, therefore, are not included in this assessment.

Overall, Option 1 will provide low benefit to Sacramento River salmon and steelhead compared to base conditions. The potential opportunities for habitat restoration/enhancement under Option 1 were the lowest among the four Options evaluated.

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[1] Because life history characteristics of steelhead are not well understood and are broadly similar (based on what is known) to Chinook salmon life history characteristics, this analysis treats steelhead and Chinook similarly. Important differences are distinguished in the text. Because there are four runs of Chinook salmon that spawn in the Sacramento River (fall-/late fall-, spring, and winter-runs), differences among runs are noted as relevant to the evaluation.

Based on the evaluation of each biological criterion presented below, Table 3-X and Table 3-X summarize the expected degree to which Option 1 would be expected to affect Sacramento salmonids relative to base conditions.

Table 3-3. Summary of Expected Effects of Option 1 on Highly and Moderately Important Sacramento River Chinook Salmon Stressors

Stressors[1]	Applicable Criteria	Option Effects on Important Species Stressors Relative to Base Conditions	
		Scenario A	Scenario B
Highly Important Stressors			
Reduced staging and spawning habitat	2,3	No net effect	No net effect
Reduced rearing and outmigration habitat	2,3	Low benefit	Moderate benefit
Predation by non-native species	1,5	Low benefit	Low benefit
Moderately Important Stressors			
Harvest	1	No net effect	No net effect
Reduced genetic diversity/ integrity	1	No net effect	No net effect
SWP/CVP entrainment	1,4	No net effect	Moderate benefit
Exposure to toxics	1,2	No net effect	No net effect
Increased water temperature	2,3	No net effect	No net effect

Notes:
1. See Appendix C for descriptions of stressors, stressor impact mechanisms, and stressor effects.

Table 3-4. Summary of Expected Effects of Option 1 on Highly and Moderately Important Sacramento River Steelhead Stressors

Stressor[1]	Applicable Criteria	Option Effects on Important Species Stressors Relative to Base Conditions	
		Scenario A	Scenario B
Highly Important Stressors			
Reduced staging and spawning habitat	2,3	No net effect	No net effect
SWP/CVP entrainment	1,4	No net effect	No net effect
Reduced rearing and outmigration habitat	2,3	Low benefit	Moderate benefit
Predation by non-natives	1,5	Low benefit	Low benefit
Moderately Important Stressors			
Exposure to toxics	1,2	No net effect	No net effect
Reduced genetic diversity/ integrity	1	No net effect	No net effect

Table 3-4. Summary of Expected Effects of Option 1 on Highly and Moderately Important Sacramento River Steelhead Stressors (continued)

Stressor[1]	Applicable Criteria	Option Effects on Important Species Stressors Relative to Base Conditions	
		Scenario A	Scenario B
Harvest	1	No net effect	No net effect
Increased water temperature	2,3	No net effect	No net effect

Notes:

1. See Appendix C for descriptions of stressors, stressor impact mechanisms, and stressor effects.

3.1.3.1 Criterion #1. Relative degree to which the Option would reduce species mortality attributable to non-natural mortality sources, in order to enhance production (reproduction, growth, survival), abundance, and distribution for each of the covered fish species.

Based on the best available scientific information, the primary stressors that contribute to non-natural mortality of Sacramento River salmonids and that can be differentially influenced by the four Options include:

Chinook salmon	**Steelhead**
Predation by non-native fish	Entrainment/salvage
Entrainment/salvage	Predation by non-native fish
Exposure to toxics	Exposure to toxics
Exposure to elevated water temperatures	Exposure to elevated water temperatures

It is thought that predation by non-native species is a lower stressor contributing to non-natural mortality of steelhead than Chinook salmon. Juvenile steelhead are typically larger when migrating through the Delta and are, therefore, expected to have a lower vulnerability to predation mortality when compared to juvenile Chinook salmon. Conclusions below incorporate this difference between steelhead and Chinook salmon. The assessment of Option 1 evaluated, in part, the degree to which the Option addressed these stressors.

Overall, Option 1 is expected to provide a very low reduction in non-natural mortality for Sacramento River salmonids.

Predation by non-native species

A variety of non-native predatory fish species have established sustainable populations within the Delta, including striped bass and largemouth bass (Moyle 2002). Three primary mechanisms influence the degree to which non-native predation affects juvenile salmonids.

First, colonies of non-native aquatic vegetation, such as *Egeria densa* and water hyacinth, grow in dense stands that prohibit access to and reduce quality of shallow water channel margins on which salmonids rear, forcing salmonids into deeper water and exposing them to higher predation risk (Grimaldo et al. 2000). Second, the gravel pits and in-stream flooded ponds, in addition to the operation of water control gates and weirs, can attract non-native predators and expose juvenile salmonids to higher predation risk from the lack of cover. Because this mechanism occurs upstream of the Delta, it is not expected to be affected by the Options, and will not be discussed further. Third, it has been hypothesized that changes in habitat quality and characteristics within the Delta (e.g., construction of riprap protected levees, construction of a number of structures, and the reduction of natural cover) have increased the vulnerability of juvenile salmonids to predation (NOAA 2005). Although the control of these non-native predators is difficult, one approach to addressing the issue of increased vulnerability to predation by non-natives is to enhance the quality and availability of habitat, including cover habitat, for native species (Lund et al. 2007). Although there is a high degree of uncertainty concerning the effectiveness of reducing versus enhancing non-native predator populations under this action, it is assumed for purposes of this assessment that increasing habitat quantity and quality will benefit salmonids and reduce the impacts of predation mortality by non-native fish species. Approximately 28% of the Delta is potentially available for restoration/ enhancement under this Option (Figure 1-2), but much of the range of Sacramento River salmonids within the Delta would be within this area (e.g., northern and western regions of the Delta located along the migration corridor for Sacramento River salmonids). Improvements in the hydraulics and flows entering several channels on the Sacramento River (e.g., Sutter and Steamboat sloughs, Yolo Bypass, etc.) that would be available under this Option would provide alternative migration routes for juvenile salmonids that would potentially reduce their exposure to sources of mortality within the Delta. Risk to predation mortality can decrease with increased turbidity. Overall, Option 1 would provide a low reduction in mortality by non-native predation.

Entrainment

Operation of the SWP and CVP export facilities results in the entrainment and salvage of juvenile Chinook salmon and steelhead. The vulnerability of salmon and steelhead to export related losses varies in response to a number of factors including distribution of salmonids within the Delta, operation of Delta Cross-Channel gates, hydrodynamic conditions occurring within the central and southern regions of the Delta (e.g., Old and Middle rivers), and export rates (USBR and DWR, unpubl. data). The risk of entrainment by the SWP/CVP export facilities can be estimated as the magnitude of reverse flows in Middle and Old rivers and an index of vulnerability for salmon and steelhead to salvage at the export facilities. When combined reverse flows in Old and Middle rivers are negative (reverse flow direction) the vulnerability of juvenile Chinook salmon and steelhead to SWP and CVP exports is expected to increase. Hydrologic model results indicate that operations under Option 1would potentially result in a similar level of entrainment risk as under the base conditions. The vulnerability index indicates that Option 1 would provide a minimal reduction in entrainment risk (<8% of base conditions). Overall, entrainment would be similar to base conditions under Option 1.

Exposure to toxics

There is evidence that toxics can impact juvenile salmonids (DFG 1996, USBR 2004, Klnick et al. 2005). As indicated in the delta smelt section above, flows into the Delta to dilute toxics are not expected to be different under Option 1 than under base conditions. The potential significance of exposure by juvenile salmonids to toxics may be reduced, in part, by their relatively short period of residency in the Delta relative to delta smelt. However, the fact that the majority of juvenile salmonids migrate through the Delta during the late winter and spring, in contrast, may result in an increased vulnerability to toxic exposure resulting from stormwater runoff and other point and non-point sources.

3.1.3.2 Criterion #2. Relative degree to which the Option would provide water quality and flow conditions necessary to enhance production (reproduction, growth, survival), abundance, and distribution for each of the covered fish species.

Water quality changes that impact Sacramento River salmonids can be measured as differences in exposure to toxics and water temperature[2] relative to base conditions. Flow conditions can affect the quality, quantity, and accessibility of habitat.

Overall, Option 1 would be expected to provide no benefits to habitat conditions for salmonids based on water quality and flow conditions compared to base conditions.

Exposure to toxics

Dilution flows that decrease concentrations of toxics would be similar under Option 1 to those under base conditions. Therefore, Option 1 would not change exposure of Sacramento River salmonids to toxics.

Rearing habitat

The location of X_2 affects the location of the low salinity zone, and potentially habitat quality and availability for juvenile rearing salmonids within Suisun Bay and the western Delta. Higher outflows tend to locate X_2 further downstream, which would potentially provide improved habitat for juvenile salmonid rearing during the late winter and spring. Results of the hydrologic modeling for Option 1 show that the change in location of X_2 in April relative to base conditions under Option 1 is 0.5 km upstream, which would result in a negligible adverse effect to rearing habitat for juvenile salmon during the late winter and spring. Dilution flows to reduce the concentrations of toxics will not change appreciably under Option 1 in rearing habitat of juvenile salmonids.

Net downstream flows are important to the migration of salmonids to downstream rearing habitat. Positive relationships have been identified between Sacramento River flow and juvenile salmon survival during migration (P. Brandes, unpubl. data). Model output indicates

[2] Under the current Delta configuration and that of Option 1, dissolved oxygen is limiting in specific areas of the Delta (i.e., the Stockton Ship Channel, adjacent to discharges in Suisun Marsh from managed wetlands) during times of year, however these typically occur in areas where Sacramento River Chinook salmon and steelhead would not be expected to occur. Therefore, dissolved oxygen is not expected to be a major stressor to juvenile salmon or steelhead migrating from the Sacramento River downstream through the Delta.

that both Rio Vista flows and total Delta outflow under Option 1 would be approximately equal to base conditions for all water year types in both months (Table ____), indicating that Option 1 would provide no benefit to downstream flows for Sacramento River salmonids.

Access to staging and spawning habitat

Although staging and spawning habitat occurs upstream of the Delta, actions in the Delta are influenced differentially by the four Options. Changes in Sacramento River flows are likely to affect attraction and migratory cues for adults to reach upstream spawning habitat (Hasler and Cooper 1976). Sacramento River inflows at Rio Vista indicate that Option 1 would not change inflows and, therefore, not alter migratory cues.

3.1.3.3 Criterion #3. Relative degree to which the Option would increase habitat quality, quantity, accessibility, and diversity in order to enhance and sustain production (reproduction, growth, survival), abundance, and distribution; and to improve the resiliency of each of the covered species' populations to environmental change and variable hydrology.

The two important parameters that affect habitat quality, quantity, accessibility, and diversity of Sacramento River salmonids include (Appendix C): reduced access to adult staging and spawning habitat and reduced quality, quantity, accessibility, and diversity of juvenile rearing habitat.

Overall, Option 1 would support a low increase in habitat quality and availability for Sacramento River salmonids.

Staging and spawning habitat

Low seasonal flows can influence the attraction and accessibility of upstream adult salmonid staging and spawning habitat because salmonids may be unable to sense migratory cues from upstream or stray because of false cues from flows that pass through intermediate waterways (i.e., the central Delta) before reaching downstream. Flow conditions under Option 1, as reported in Criterion 2 above, would be negligibly different from base conditions. As a result, access to spawning habitat would not be affected by Option 1. Reservoir releases under Option 1 would be similar to base conditions, indicating that water temperatures would be similar in upstream spawning grounds to base conditions. Overall, these results indicate that the effect of Option 1 on upstream spawning habitat conditions would be minimal.

Rearing habitat

The location of X_2 is expected to be farther upstream by 0.5 km. This small change in rearing habitat would have a negligible effect to salmonids. The quantity, quality, accessibility, and diversity of juvenile salmonid rearing habitat within the Delta has been affected by a number of factors including changes in hydrodynamic conditions, reductions in tidal and shallow subtidal habitat, and construction of riprap protected levees. Under Option 1 approximately 28% of the habitat in the Delta would potentially be available for restoration/enhancement (Figure 1-2). Much of this habitat is located in the northern region of the Delta along the migration pathway for Sacramento River salmonids. Habitat improvement in this region of the Delta would be expected to provide a low benefit for salmonids migrating from the Sacramento River. As described in Criterion #2, downstream flows under Option 1, which affect access of migrating salmonids to their rearing habitat, would not be expected to change relative to base conditions.

3.1.3.4 Criterion #4. Relative degree to which the Option would increase food quality, quantity, and accessibility (e.g., phytoplankton, zooplankton, macro-invertebrates, forage fish) to enhance production (reproduction, growth, survival) and abundance for each of the covered fish species.

Juvenile Chinook salmon and steelhead forage on a variety of macroinvertebrates (e.g., copepods, amphipods) and small fish during their residency within the Delta. The abundance of these prey species varies in response to a number of factors that include availability of nutrients, organic carbon, phytoplankton and zooplankton production. Reduced food availability or quality, however, are not identified as important stressors for Sacramento River salmonids. Consequently, benefits of increasing food quantity and quality under the Options would not be expected to result in a population level response relative to base conditions.

3.1.3.5 Criterion #5. Relative degree to which the Option would reduce the abundance of non-native competitors and predators to increase native species production (reproduction, growth, survival), abundance and distribution for each of the covered fish species.

One method for reducing population impacts to, and promoting populations of, juvenile salmonids by non-native species is to restore Delta habitat to mimic historical habitat conditions (Lund et al. 2007). Under Option 1, approximately 28% of the Delta would potentially be available for effective restoration/enhancement, the lowest of all the Options evaluated in this assessment. This restoration is located primarily in the northern and western regions of the Delta and overlaps habitat that is thought to be important for juvenile Chinook salmon and steelhead emigrating from the Sacramento River. Therefore, this Option would provide low benefit to Sacramento River salmonids.

3.1.3.6 Criterion #6. Relative degree to which the Option improves ecosystem processes in the BDCP planning area to support aquatic and associated habitats.

Measurements used to assess the potential for Option 1 to improve ecosystem processes included (1) PTM modeling results for hydraulic residence time in the central Delta and (2) the proportion of the Delta expected to be suitable for restoration of aquatic and intertidal habitat. Based on the proportion of the planning area suitable for restoration under Option 1 relative to the other Options and modeling results for hydraulic residence time (see Appendix H), Option 1 would be expected to provide a very low beneficial improvement in ecosystem function relative to base conditions because habitat restoration under Option 1 would improve ecosystem processes, hydraulic residence time would be similar to base conditions. Under Option 1, Delta channels would continue to serve as the water conveyance facilities for freshwater supplies moving from the Sacramento River across the Delta to the export facilities in the south Delta. Movement of large volumes of water through these channels would adversely affect hydraulic conditions within the Delta (e.g., reverse flows), affect salinity levels and distribution, require riprapped levees to reduce erosion and levee scour, and limit the opportunities for habitat enhancement. The hydraulic conditions within the Delta under these operations would continue to reduce hydraulic residence times and export nutrients, organic carbon, phytoplankton, and zooplankton from the Delta resulting in adverse effects on aquatic food production and availability.

3.1.3.7 Criterion #7. Relative degree to which the Option can be implemented within a timeframe to meet the near-term needs of each covered fish species (post BDCP authorization).

Habitat restoration under Option 1 can be initiated immediately following authorization of the BDCP and thus could be implemented in a manner that would meet the near term needs of Sacramento River salmonids. The implementation period for Option 1 is the same as the other Options.

3.1.4 San Joaquin River Salmonids[3]

The San Joaquin River tributaries produce fall-run Chinook salmon and provide habitat for what appears to be a small population of steelhead. Recent monitoring has detected small self-sustaining populations of steelhead in the Stanislaus, Mokelumne, and Calaveras rivers, and other streams previously thought to be devoid of steelhead (McEwan 2001). As part of the assumptions used to compare the potential performance of various Options on fishery habitat a decision was made to maintain San Joaquin River flows as outlined in either the VAMP agreement or D-1641. The purpose of this analysis is therefore not intended to assess changes in upstream habitat conditions or factors affecting salmonid survival but rather to focus only on potential changes in conditions within the Delta that may affect San Joaquin River salmonids. Because many of the factors that affect Sacramento River salmonids discussed in the previous section also affect San Joaquin River salmonids, those similarities have been noted but not repeated in their entirety in this section.

Overall, Option 1 will provide very low benefit to San Joaquin River salmon and steelhead compared to base conditions. The potential opportunities for habitat restoration/enhancement under Option 1 were the lowest among the four Options evaluated and a portion of this area would likely not be utilized by salmonids originating in the San Joaquin River and tributaries.

Based on the evaluation of each biological criterion presented below, Table 3-X and Table 3-X summarize the degree to which Option 1 would be expected to affect San Joaquin River origin salmonids relative to base conditions.

[3] Because life history characteristics of steelhead are not well understood and are broadly similar (based on what is known) to Chinook salmon life history characteristics, this analysis treats steelhead and Chinook similarly. Important differences are distinguished in the text.

Table 3-5. Summary of Expected Effects of Option 1 on Highly and Moderately Important San Joaquin River Chinook Salmon Stressors

Stressor[1]	Applicable Criteria	Option Effects on Important Species Stressors Relative to Base Conditions	
		Scenario A	Scenario B
Highly Important Stressors			
Reduced staging and spawning habitat	2,3	No net effect	No net effect
Reduced rearing and outmigration habitat	2,3	Low benefit	Low benefit
Exposure to toxics	1,2	No net effect	No effect
Predation by non-natives	1,5	Very low benefit	Very low benefit
Moderately Important Stressors			
Reduced genetic diversity/ integrity	1	No net effect	No net effect
Harvest	1	No net effect	No net effect
SWP/CVP entrainment	1,4	No net effect	Moderate benefit
Increased water temperature	2,3	No net effect	No net effect

Notes:
1. See Appendix C for descriptions of stressors, stressor impact mechanisms, and stressor effects.

Table 3-6. Summary of Expected Effects of Option 1 on Highly and Moderately Important San Joaquin River Steelhead Stressors

Stressor[1]	Applicable Criteria	Option Effects on Important Species Stressors Relative to Base Conditions	
		Scenario A	Scenario B
Highly Important Stressors			
Reduced staging and spawning habitat	2,3	No net effect	No net effect
Reduced rearing and outmigration habitat	2,3	Very low benefit	Low benefit
Exposure to toxics	1,2	No net effect	No net effect
Reduced genetic diversity/ integrity	1	No net effect	No net effect
Predation by non-natives	1,5	Very low benefit	Very low benefit
Moderately Important Stressors			
SWP/CVP entrainment	1,4	Very low benefit	Moderate benefit
Harvest	1	No net effect	No net effect
Increased water temperature	2,3	No net effect	No net effect

Notes:
1. See Appendix C for descriptions of stressors, stressor impact mechanisms, and stressor effects.

3.1.4.1 Criterion #1. Relative degree to which the Option would reduce species mortality attributable to non-natural mortality sources, in order to enhance production (reproduction, growth, survival), abundance, and distribution for each of the covered fish species.

The relative degree to which Option 1 would reduce sources of mortality for San Joaquin River Chinook salmon and steelhead and other identified stressors is summarized in Tables 3-5 and 3-6. Overall, the range of operations reflected in Option 1 would have a low benefit on reducing stressors on salmonids during their migration through the Delta.

Based on the best available scientific information, the primary stressors that contribute to non-natural mortality of San Joaquin River salmonids and that can be differentially influenced by the four Options include (see Figures 2-5, 2-6 and Appendix C):

Chinook salmon	Steelhead
Exposure to toxics	Exposure to toxics
Predation by non-native fish	Predation by non-native fish
Entrainment/salvage	Entrainment/salvage
Exposure to elevated water temperatures	Exposure to elevated water temperatures

The effect of these stressors on the salmon and steelhead populations vary among years in response to environmental conditions (e.g., seasonal hydrology) and may also interact with each other in additive or synergistic ways. No single stressor has been identified, with confidence, as the primary factor affecting the current status of Chinook salmon or steelhead. The effects of these stressors include both the incremental contribution of a stressor to the population as well as the cumulative effects of multiple stressors over time. The assessment of Option 1 evaluated, in part, the degree to which the Option addressed these stressors.

The ability of Option 1 to address the stressors affecting San Joaquin River origin salmonids is very limited. As a result of the continued use of Old and Middle rivers as primary water conveyance facilities through the Delta reverse flow conditions would be expected to continue and limit habitat enhancement opportunities in the central and southern Delta and the vulnerability of juveniles to entrainment and salvage at the SWP and CVP export facilities. Under Option 1 the potential for habitat enhancement to provide direct benefits to salmonids (cover and foraging habitat) as well as contribute to increased food availability are located in the northern and western regions of the Delta (Figure 1-2). These habitat enhancement features would be expected to provide little or no benefit to San Joaquin River salmonids during their downstream migration through the Delta. Habitat conditions along the lower San Joaquin River would be expected to be similar under Option 1 as current base conditions.

Exposure to toxics

The preferred method of reducing the risk of toxicity to salmonids within the Delta is through source control that could be applied across all of the Options included in this assessment. Dilution flows from the Sacramento River are another way of reducing concentrations of toxics and their effect on salmonids. For purposes of this assessment, the effects of dilution flows from the Sacramento River discussed in Sacramento River salmonids section are expected to be applicable to San Joaquin River salmonids. Because water quality conditions within the San Joaquin River are poorer and potential pollutant loading is greater, changes in dilution flows from the Sacramento River may have a lower effect on reducing the exposure and potential adverse effects within the southern and central Delta on San Joaquin River salmonids. Therefore, Option 1 is not expected to reduce exposure to toxics of San Joaquin River salmonids.

Predation by non-native fish

Under Option 1, the potential for restoration with the goal of reducing habitat conditions for non-native fish, thereby reducing predation risk of San Joaquin River Chinook salmon, is low. Steelhead are typically larger when migrating through the Delta and, therefore, are expected to have a lower vulnerability to predation mortality when compared to juvenile Chinook salmon.

Entrainment

The index of entrainment of San Joaquin River salmonids is expected to be marginally lower under Option 1 relative to base conditions. Model output indicates that the magnitude of reverse flows under Option 1 is also expected to be marginally lower. Therefore, overall, Option 1 will provide a very low benefit to entrainment risk relative to base conditions.

3.1.41.2 Criterion #2. Relative degree to which the Option would provide water quality and flow conditions necessary to enhance production (reproduction, growth, survival), abundance, and distribution for each of the covered fish species.

Overall, water quality and flow conditions Option 1 would be expected to be similar to base conditions.

Exposure to toxics

As discussed under the previous criterion, Option 1 is not expected to change the exposure to toxics of San Joaquin River salmonids.

Rearing habitat

The location of X_2 will be 0.5 km upstream under Option 1, indicating that the Option will cause a negligible adverse effect to rearing habitat for juvenile salmon during the late winter and spring. As previously stated, the assumption was made to maintain San Joaquin River flows for modeling efforts to meet VAMP agreement or D-1641 flow standards. Therefore, the differences among Options in Vernalis flow, a metric for downstream movement of salmonids towards Delta rearing and emigration habitat, would be minimal among the Options.

Combined, this indicates that Option 1 will do little to improve water quality and flow conditions to increase the quality and availability of San Joaquin River salmonid rearing habitat.

Dissolved oxygen is limiting in specific areas of the Delta (i.e., the Stockton Ship Channel) during seasonal period when San Joaquin River salmonids are migrating upstream or downstream. The actions included in Option 1 would not be expected to change localized dissolved oxygen levels when compared to current base conditions.

Access to staging and spawning habitat

Changes in hydrodynamic conditions within central and south Delta channels under Option 1 are not expected to affect migration cues for adult and juvenile salmonids relative to base conditions. There are no major changes to the pathways or flow rates under this Option

3.1.4.3 Criterion #3. Relative degree to which the Option would increase habitat quality, quantity, accessibility, and diversity in order to enhance and sustain production (reproduction, growth, survival), abundance, and distribution; and to improve the resiliency of each of the covered species' populations to environmental change and variable hydrology.

Overall, Option 1 is expected to have a very low beneficial effect on the habitat quality, quantity, accessibility, and diversity for San Joaquin River salmonids.

Staging and spawning habitat

As indicated under Criterion 1, migratory cues are not expected to change under Option 1 relative to base conditions.

Rearing habitat

The small change in X_2 under Option 1 will have no effect on rearing habitat of salmonids. Approximately 28% of the habitat in the Delta would potentially be available for restoration/enhancement (Figure 1-2). A large portion of this habitat is located in the northern region of the Delta away from the migration pathway for San Joaquin River salmonids. Therefore, the opportunities available for restoration/enhancement under Option 1 would provide low benefit to San Joaquin River salmonids. As described in Criterion 2, Vernalis flows will not change among the Options.

3.1.4.4 Criterion #4 Relative degree to which the Option would increase food quality, quantity, and accessibility (e.g., phytoplankton, zooplankton, macro-invertebrates, forage fish) to enhance production (reproduction, growth, survival) and abundance for each of the covered fish species.

Juvenile Chinook salmon and steelhead forage on a variety of macroinvertebrates (e.g., copepods, amphipods) and small fish during their residency within the Delta. The abundance of these prey species varies in response to a number of factors that include availability of nutrients, organic carbon, phytoplankton and zooplankton production. Reduced food availability or quality, however, are not identified as important stressors for San Joaquin River salmonids. Consequently, benefits of increasing food quantity and quality under the Options would not be expected to result in a population level response relative to base conditions.

3.1.4.5 Criterion #5. Relative degree to which the Option would reduce the abundance of non-native competitors and predators to increase native species production (reproduction, growth, survival), abundance and distribution for each of the covered fish species.

Under Option 1, the southern and central Delta channels and aquatic habitat would be similar to current conditions (Figure 1-2). Opportunities under Option 1 to affect the abundance on non-native species of competitors and predators that would benefit San Joaquin River salmonids are expected to be very low.

3.1.4.6 Criterion #6. Relative degree to which the Option improves ecosystem processes in the BDCP planning area to support aquatic and associated habitats.

Measurements used to assess the potential for Option 1 to improve ecosystem processes included (1) PTM modeling results for hydraulic residence time in the central Delta and (2) the proportion of the Delta expected to be suitable for restoration of aquatic and intertidal habitat. Based on the proportion of the planning area suitable for restoration under Option 1 relative to the other Options and modeling results for hydraulic residence time (see Appendix H), Option 1 would be expected to provide a very low beneficial improvement in ecosystem function relative to base conditions because habitat restoration under Option 1 would improve ecosystem processes, hydraulic residence time would be similar to base conditions. Under Option 1, Delta channels would continue to serve as the water conveyance facilities for freshwater supplies moving from the Sacramento River across the Delta to the export facilities in the south Delta. Movement of large volumes of water through these channels would adversely affect hydraulic conditions within the Delta (e.g., reverse flows), affect salinity levels and distribution, require riprapped levees to reduce erosion and levee scour, and limit the opportunities for habitat enhancement. The hydraulic conditions within the Delta under these operations would continue to reduce hydraulic residence times and export nutrients, organic carbon, phytoplankton, and zooplankton from the Delta resulting in adverse effects on aquatic food production and availability.

3.1.4.7 Criterion #7. Relative degree to which the Option can be implemented within a timeframe to meet the near-term needs of each covered fish species (post BDCP authorization).

Habitat restoration under Option 1 can be initiated immediately following authorization of the BDCP and thus could be implemented in a manner that would meet the near term needs of San Joaquin River salmonids. The implementation period for Option 1 is the same as the other Options.

3.1.5 Green and White Sturgeon

Based on the evaluation presented below of the expected performance of Option 1 for addressing important green sturgeon and white sturgeon stressors, Option 1 would be expected to have a low beneficial effect on green sturgeon production, distribution, and abundance and a very low effect on white sturgeon relative to base conditions when operated to meet water supply objectives (Scenario A). If water supply exports were reduced (Scenario B), Option 1 would be expected to provide a similar level of benefit for sturgeon production, distribution, and abundance relative to base conditions. Option 1 would be expected to provide the lowest benefits for sturgeon compared to the other Options.

Stressors that affect sturgeon are presented in Figures 2-7 and 2-8 and are described in Appendix C. The effect of these stressors on the green and white sturgeon populations vary among years in response to environmental conditions (e.g., seasonal hydrology) and may also interact with each other in additive or synergistic ways. The effects of these stressors include both the incremental contribution of a stressor to the population as well as the cumulative effects of multiple stressors over time. The assessment of Option 1 evaluates the degree to which Option 1 would be expected to address these stressors.

Tables 3-7 and 3-8, respectively, summarize the expected effects of implementing Option 1 under Scenarios A and B on important sturgeon stressors relative to base conditions.

Table 3-7. Summary of Expected Effects of Option 1 on Highly and Moderately Important Green Sturgeon Stressors

Stressors[1]	Applicable Criteria	Option Effects on Important Species Stressors Relative to Base Conditions	
		Scenario A	Scenario B
Highly Important Stressors			
Reduced spawning habitat	3	No net effect	No net effect
Exposure to toxics	1,2,3	No net effect	No net effect
Harvest	1	No net effect	No net effect
Moderately Important Stressors			
Reduced rearing habitat	1,2,3	Low benefit	Low benefit
Increased water temperature (upstream)	1,2,3	No net effect	No net effect
Predation	1,3	No net effect	No net effect
Reduced turbidity	1,2,3	No net effect	No net effect

Notes:
1. See Appendix C for descriptions of stressors, stressor impact mechanisms, and stressor effects.

Table 3-8. Summary of Expected Effects of Option 1 on Highly and Moderately Important White Sturgeon Stressors

Stressors[1]	Applicable Criteria	Option Effects on Important Species Stressors Relative to Base Conditions	
		Scenario A	Scenario B
Highly Important Stressors			
Harvest	1	No net effect	No net effect
Reduced spawning habitat	3	No net effect	No net effect

Table 3-8. Summary of Expected Effects of Option 1 on Highly and Moderately Important White Sturgeon Stressors (continued)

Stressors[1]	Applicable Criteria	Option Effects on Important Species Stressors Relative to Base Conditions	
		Scenario A	Scenario B
Exposure to toxics	1,2,3	No net effect	No net effect
Moderately Important Stressors			
Reduced rearing habitat	1,2,3	Very low benefit	Very low benefit
Increased water temperature (upstream)	1,2,3	No net effect	No net effect
Predation	1,3	No net effect	No net effect
Reduced turbidity	1,2,3	No net effect	No net effect

Notes:

1. See Appendix C for descriptions of stressors, stressor impact mechanisms, and stressor effects.

Harvest, reduced spawning habitat, predation, reduced turbidity, and increased water temperatures are not important stressors that would be affected by or affected differently (i.e., harvest, reduced spawning habitat) under the Options and, therefore, are not described in the criteria evaluations below (see Table 2-3 and Appendix C). These stressors could only be addressed through changes in regulation and law enforcement (for harvest) or through conservation actions implemented outside of the planning area. Any effects within the planning area of the Options on the non-harvest stressors described above would not be expected to have any benefits to sturgeon at the population level. As described in Table 2-3, the ability to address harvest and reduced spawning habitat within the planning area would be the same among the Options. Consequently, these stressors are initially identified under the applicable criteria below, but are not evaluated under the criteria.

3.1.5.1 Criterion #1. Relative degree to which the Option would reduce species mortality attributable to non-natural mortality sources, in order to enhance production (reproduction, growth, survival), abundance, and distribution for each of the covered fish species.

Important stressors that cause non-natural mortality of green and white sturgeon (see Appendix C) are:

- Harvest,
- Exposure to toxics,
- Reduced rearing habitat,
- Increased water temperature (upstream),
- Predation, and
- Reduced turbidity.

Based on the following evaluation of Option 1 effects on applicable green and white sturgeon stressors, the risk for sturgeon mortality from non-natural causes under Option 1 is expected to be similar to base conditions.

Exposure to Toxics

Exposure of green and white sturgeon to toxic substances can result in mortality of sturgeon. The effects of Option 1 on exposure to toxics are evaluated under Criteria #2 and #4 below. As described in the Criteria #2 and #4 evaluations, the risk for exposure to toxics under Option 1 would be expected to be similar to base conditions.

3.1.5.2 Criterion #2. Relative degree to which the Option would provide water quality and flow conditions necessary to enhance production (reproduction, growth, survival), abundance, and distribution for each of the covered fish species.

Important stressors that affect water quality and flow conditions for green and white sturgeon (see Appendix C) are:

- Exposure to toxics,
- Reduced rearing habitat,
- Increased water temperature (upstream), and
- Reduced turbidity.

Based on the following evaluation of Option 1 effects on applicable green and white sturgeon stressors, Option 1 is expected to provide no benefits for water quality and flow conditions that support green and white sturgeon relative to base conditions.

Exposure to toxics

Exposure of sturgeon to toxic substances can result from point and non-point sources associated with agricultural, urban, and industrial land uses. No specific causal link has been established between sturgeon exposure to toxic events on a large-scale within the Delta and subsequent growth or survival. There is inconsistent evidence that the invertebrate prey of green and white sturgeon is affected by toxics. Green and white sturgeon are long-lived species that forage primarily on benthic organisms and therefore are affected by chronic exposure to pollutants through bioaccumulation of toxics such as selenium. Bioaccumulation of selenium has been demonstrated to be a factor affecting green and white sturgeon production and survival. *Corbula* and *Corbicula*, which are filter-feeding clams that capture selenium, are a non-native food source that has become established in the western Delta and Suisun Bay. Consumption of these clams by sturgeon has resulted in the bioaccumulation of selenium in the sturgeon (EPIC et al 2001, Moyle 2002, Doroshov 2006). Reductions in selenium loads within the Delta would not be affected by any of the Options. Currently, the most likely effective method for reducing selenium loads within the Delta would be source reduction in areas located upstream of the Delta.

Two factors affecting the degree of potential exposure of sturgeon to toxics include hydraulic residence time in habitat, which effects the period of exposure to toxics, and flows from the Sacramento River and other Delta tributaries, which can dilute concentrations of toxics. Measurements used to assess the potential effects of Option 1 on exposure to toxics included (1) PTM modeling results for CVP/SWP for particle fate in the central Delta, (2) Sacramento River flows at Rio Vista, and (3) Delta outflow during March and April. Overall, residence time within the central Delta under Option 1 was highly variable but on average similar to base conditions (sees Appendices D and H). Modeling results indicate that the toxics dilution potential of Option 1 would be similar to base conditions (see Appendices D and H).

Reduced Rearing Habitat

Results of fishery sampling conducted by CDFG suggest that the abundance of juvenile sturgeon within the Delta increases with increasing flow in the Sacramento River and Delta Inflows. The location of X_2 affects the location of the low salinity zone, and can be used as an indicator of habitat quality and availability for green and white sturgeon. Higher outflows tend to locate X_2 further downstream, which would potentially provide improved habitat for green and white sturgeon rearing during the late winter and spring. Hydrologic modeling results for Option 1 show that the change in location of X_2 in April relative to base conditions was 0.5 km upstream. This indicates that the low salinity zone would be similar to base conditions under Option 1.

3.1.5.3 Criterion #3. Relative degree to which the Option would increase habitat quality, quantity, accessibility, and diversity in order to enhance and sustain production (reproduction, growth, survival), abundance, and distribution; and to improve the resiliency of each of the covered species' populations to environmental change and variable hydrology.

Important stressors that cause non-natural mortality of green and white sturgeon (see Appendix C) are:

- Reduced spawning habitat
- Exposure to toxics,
- Reduced rearing habitat,
- Increased water temperature (upstream),
- Predation, and
- Reduced turbidity.

Within the planning area, green and white sturgeon habitat conditions are governed by hydrodynamic conditions and the extent and quality of habitat within the planning area. Under Option 1, these conditions relative to base conditions would be affected by the conveyance configuration of Option 1 and restoration of physical habitat that could be sited within Suisun

Bay and Marsh and within the planning area in the north and west Delta, which represents approximately 28% of the planning area.

Based on the following evaluation of Option 1 effects on applicable green and white sturgeon stressors, Option 1 is expected to provide low habitat benefits for green sturgeon and very low habitat benefits for white relative to base conditions.

Exposure to Toxics

As described under Criterion #2 above, the risk for exposure of sturgeon to toxics is similar to base conditions. A major source for bioaccumulation of selenium in sturgeon is consumption of non-native *Corbula* and *Corbicula* which capture selenium from Delta waters. Restoration of aquatic shallow subtidal and intertidal habitats could create conditions that favor the production of alternative prey (e.g., bay shrimp) that reduce the risk of bioaccumulation of materials such as selenium for juvenile and adult sturgeon. The potential success of reducing the risk of toxics on sturgeon through habitat improvements and increased production of alternative prey resources is uncertain. Under Option 1, habitat could potentially be restored within Suisun Bay and Marsh and approximately 28% of the Delta to provide high quality aquatic habitat under this option (Figure 1-2). Because habitat could be restored within a more limited geographic range than under the other Options, Option 1 would be expected to provide very low benefit to white sturgeon by reducing their exposure to selenium. Because green sturgeon are not known to inhabit the San Joaquin River watershed, restoration under Option 1 would provide a low level of benefit to green sturgeon, which would be the same as under Options 2 and 3, but less than under Option 4 which provides the ability to restore habitat in additional portions of the planning area occupied by green sturgeon.

Reduced Rearing Habitat

The primary impact mechanism believed to affect the extent of rearing habitat and rearing habitat conditions is the reclamation of historical aquatic subtidal and intertidal habitats and channelization of river channels. Under Option 1, habitat could potentially be restored within Suisun Bay and Marsh and approximately 28% of the Delta to provide high quality aquatic habitat under this Option (Figure 1-2), which encompasses a smaller proportion of white sturgeon rearing habitat than restoration that could be implemented under the other Options. Because the green sturgeon is not known to occupy the San Joaquin River watershed, restoration opportunities would be the same under Option 1 as under Options 2 and 3, but less than under Option 4, which includes restoration opportunities in the east Delta north of the San Joaquin River. Consequently, relative to base conditions and the other Options, Option 1 would be expected to provide a very low benefit for white sturgeon rearing habitat and a low benefit for green sturgeon rearing habitat.

3.1.5.4 Criterion #4. Relative degree to which the Option would increase food quality, quantity, and accessibility (e.g., phytoplankton, zooplankton, macro-invertebrates, forage fish) to enhance production (reproduction, growth, survival) and abundance for each of the covered fish species.

Reduced food availability or quality are not identified as important stressors for green and white sturgeon. Consequently, benefits of increasing food quantity and quality under the

Options would not be expected to result in a population level response relative to base conditions.

3.1.5.5 Criterion #5. Relative degree to which the Option would reduce the abundance of non-native competitors and predators to increase native species production (reproduction, growth, survival), abundance and distribution for each of the covered fish species.

Predation in the form of illegal and legal harvest would not be changed under any of the Options from base conditions.

3.1.5.6 Criterion #6. Relative degree to which the Option improves ecosystem processes in the BDCP planning area to support aquatic and associated habitats.

Measurements used to assess the potential for Option 1 to improve ecosystem processes included (1) PTM modeling results for hydraulic residence time in the central Delta and (2) the proportion of the Delta expected to be potentially available for restoration of aquatic subtidal and intertidal habitat. Based on the proportion of the planning area suitable for restoration under Option 1 relative to the other Options and modeling results for hydraulic residence time (see Appendix H), Option 1 would be expected to provide a very low beneficial improvement in ecosystem function relative to base conditions because although habitat restoration under Option 1 would improve ecosystem processes, hydraulic residence time and flow patterns within the Delta would be similar to base conditions. Under Option 1, Delta channels would continue to serve as the water conveyance facilities for freshwater supplies moving from the Sacramento River across the Delta to the export facilities located in the southern Delta. Movement of large volumes of water through these channels would adversely affect hydraulic conditions within the Delta (e.g., reverse flows), salinity levels and distribution, the need for riprapped levees to reduce erosion and levee scour, and limit the opportunities for habitat enhancement. The hydraulic conditions within the Delta under these operations would also continue to result in reduced hydraulic residence times and the export of nutrients, organic carbon, phytoplankton, and zooplankton from the Delta and thereby affect aquatic food production and availability.

3.1.5.7 Criterion #7. Relative degree to which the Option can be implemented within a timeframe to meet the near-term needs of each covered fish species (post BDCP authorization).

Habitat restoration under Option 1 can be initiated immediately following authorization of the BDCP and thus could be implemented in a manner that would meet the near term needs of green and white sturgeon. The implementation period for implementation of Option 1 is the same as the other Options.

3.1.6 Splittail

Based on the evaluation presented below of the expected performance of Option 1 for addressing important Sacramento splittail stressors, Option 1 would be expected to have a very low beneficial effect on Sacramento splittail production, distribution, and abundance relative to base conditions when operated to meet water supply objectives (Scenario A). If water supply exports are reduced (Scenario B), Option 1 would be expected to provide a low beneficial effect on splittail production, distribution, and abundance relative to base conditions. Option 1 would be expected to provide the lowest benefits for splittail compared to the other Options.

Stressors that affect Sacramento splittail are presented in Figure 2-9 and are described in Appendix C. The effect of these stressors on the splittail population vary among years in response to environmental conditions (e.g., seasonal hydrology) and may also interact with each other in additive or synergistic ways. The effects of these stressors include both the incremental contribution of a stressor to the population as well as the cumulative effects of multiple stressors over time. The assessment of Option 1 evaluates the degree to which Option 1 would be expected to address these stressors.

Table 3-9 summarizes the expected effects of implementing Option 1 under Scenarios A and B on important delta smelt stressors relative to base conditions.

Table 3-9. Summary of Expected Effects of Option 1 on Highly and Moderately Important Splittail Stressors

Applicable Criteria	Stressor[1]	Option Effects on Important Species Stressors Relative to Base Conditions	
		Scenario A	Scenario B
Highly Important Stressors			
2,3	Reduced juvenile rearing/adult habitat	Low benefit	Low benefit
2,3	Reduced spawning/larval rearing habitat	Low benefit	Moderate benefit
1,4	Reduced food	Very low benefit	Low benefit
1,2	Exposure to toxics	No net effect	Low benefit
Moderately Important Stressors			
1,5	Predation	Low benefit	Low benefit
1,4	SWP/CVP entrainment[2]	Very low benefit	Low benefit
1	Harvest	No net effect	No net effect

Notes:

1. See Appendix C for descriptions of stressors, stressor impact mechanisms, and stressor effects.
2. It is recognized that the risk of entrainment at the SWP and CVP export facilities may be a high level stressor to splittail in some years and a very low level stressor to splittail in other years. For purposes of this analysis, the risk of delta smelt entrainment has been characterized, on average, as a moderate level stressor to the population.

The Delta provides habitat for larval, juvenile, and adult Sacramento splittail. Splittail spawn primarily in seasonally inundated vegetation along channel margins and floodplain habitat located upstream within the Sacramento and San Joaquin river watersheds.

Harvest is not an important stressor that would be affected by or affected differently under the Options and, therefore, is not described in the criteria evaluations below (see Table 2-3 and Appendix C). Harvest is initially identified under the applicable criteria below, but is not evaluated under the criteria.

3.1.6.1 Criterion 1. Relative degree to which the Option would reduce species mortality attributable to non-natural mortality sources, in order to enhance production (reproduction, growth, survival), abundance, and distribution for each of the covered fish species.

Important stressors that cause non-natural mortality of Sacramento splittail (see Appendix C) are:

- Reduced food availability,
- Exposure to toxics,
- Predation,
- Entrainment by CVP/SWP facilities, and
- Harvest.

Based on the following evaluation of Option 1 effects on applicable splittail stressors, Option 1 is expected to provide very low benefits relative to base conditions by reducing the effects of non-natural sources of mortality on splittail.

The stressors that have been identified that contribute to non-natural mortality of Sacramento splittail include starvation as a result in reductions in the quantity and/or quality of available prey, exposure to toxics, predation by non-native species, risk of SWP/CVP entrainment, and harvest (Appendix C). The affect of these stressors on the splittail population vary among years in response to environmental conditions (e.g., seasonal hydrology) and may also interact with each other in additive or synergistic ways. No single stressor has been identified, with confidence, as the primary factor affecting the current status of splittail, although there is a strong relationship between the frequency and duration of seasonally inundated floodplains and the abundance of juvenile (young-of-the-year [YOY]) splittail within the Delta (Sommer et al. 1997, 2001). The effects of these stressors include both the incremental contribution of a stressor to the population as well as the cumulative effects of multiple stressors over time. The assessment of Option 1 evaluated the degree to which the option addressed these stressors.

Reduced Food Availability

Habitat conditions can affect the availability and quality of splittail food. The effects of Option 1 on splittail food availability are evaluated under Criterion #4 below. As described in the Criterion #4 evaluation, Option 1 would be expected to provide a very low beneficial effect on food supply for the splittail relative to base conditions.

Exposure to Toxics

The effect of Option 1 on exposure to toxics is addressed below under Criterion 2. Overall, toxic exposure would not be expected to change under Option 1, providing no benefits to splittail.

Predation

Under Option 1, approximately 28% of the Delta would potentially be available for restoration/enhancement (Figure 1-2), which, if designed properly, would reduce predation risk and adverse impacts of by non-native species. This entire area would be located within the geographic range of splittail within the northern and western regions of the Delta. Relative to the proportion of the splittail range within which habitat could be restored in the planning area, restoration under Option 1 would be expected to provide a low benefit for potentially reducing predation relative to base conditions and the other Options. However, there is a high degree of uncertainty regarding the biological response of splittail, other native fish and macroinvertebrate species, and non-native species to large-scale habitat restoration/ enhancement within the Delta.

Entrainment by CVP/SWP Facilities

Hydrologic model output indicates that the magnitude of reverse flows in Middle and Old rivers under Option 1 is expected to be marginally lower relative to base conditions (see Appendices D and H). The actual numbers of juveniles expected to be entrained at the SWP and CVP export facilities is expected to increase in proportion to the abundance (year class strength) of splittail in a given year (Sommer et al. 1997, Moyle et al. 2004). Therefore, few splittail are expected to be entrained when the overall population of juvenile splittail in a year is low, but large numbers may be expected to be entrained when the juvenile population is high. As a result, the risk of entrainment at the export facilities is not expected to be a significant factor in the relative reduction of population abundance in most years. During periods of extended drought during which little or no splittail production occurs and the adult population is reduced, however, a reduction in the entrainment of adults could measurably increase the reproductive potential of the population to recover following the drought period.

3.1.6.2 Criterion #2. Relative degree to which the Option would provide water quality and flow conditions necessary to enhance production (reproduction, growth, survival), abundance, and distribution for each of the covered fish species.

Factors that influence water quality conditions include dissolved oxygen, salinity, water temperature, and turbidity. Changes in these conditions are not expected to be major stressors to splittail (Appendix C) because they are well adapted to living in a highly variable tidally influenced estuarine environment (Sommer et al. 1997, Moyle et al. 2004).

Important stressors of splittail that are affected by water quality and flow conditions include (see Appendix C):

- Exposure to toxics
- Reduced juvenile rearing/adult habitat, and
- Reduced spawning/larval rearing habitat.

Based on the following evaluation of Option 1 effects on applicable splittail stressors, Option 1 is expected to no overall effect water quality and flow conditions that support splittail relative to base conditions.

Exposure to Toxics

Although there is strong support from laboratory studies that toxics can be lethal to splittail (Teh et al. 2002, 2004a,b, 2005), there is little information about the toxicity within the Delta (but see Greenfield et al. in review). Although reductions in the potential exposure of splittail and other species to toxics is expected to be most effective through source control, the risk of mortality from exposure to toxics would be expected to be reduced under conditions when higher Sacramento River flows and Delta inflows increased dilution of toxics within the Delta. For purposes of this analysis two metrics were used from the hydrologic modeling of Option 1 to assess potential changes from base conditions: flow in the Sacramento River at Rio Vista and Delta inflow during March and April. Under Option 1, flows at Rio Vista and total Delta inflow were generally equal to base conditions during March and April, (splittail spawning and YOY rearing season). This indicates that operating the Delta according to Option 1 would be expected to have no effects on the exposure of splittail to toxics.

Reduced Rearing Habitat

Reduced spring flows can reduce the rate of downstream transport of early juvenile splittail to high quality rearing habitat in the western Delta and Suisun Bay. Lower flows are expected to increase the residence time of young splittail in areas of lower productivity and food supplies within the upstream rivers and central Delta, and may lead to an increased risk of entrainment at the SWP/CVP export facilities, exposure to lower environmental conditions that could reduce growth and survival, and increased probability of exposure to contaminants toxics derived from upstream areas and within the Delta (Moyle et al. 2004). Hydrologic model output for Sacramento River flows at Rio Vista and total Delta outflow during March and April were used in the analysis of potential differences in downstream transport flows relative to base conditions. Particle tracking results were not used in this part of the analysis because, unlike larval delta and longfin smelt, juvenile splittail do not behave as neutrally buoyant particles and can actively swim downstream (Moyle et al. 2004). Results of hydrologic model simulations for Option 1 indicated that Rio Vista flows and total Delta outflows were generally similar to base conditions. These results indicate that transport of YOY splittail into the Delta from the upstream under Option 1 is expected to be similar to base conditions.

Reduced Spawning Habitat

Splittail primarily spawn in seasonally inundated floodplain habitat. Changes in hydrologic conditions within the watersheds (e.g., operation of reservoirs for flood control) and construction of levees have reduced the availability and access of floodplains for splittail spawning. Peak Delta inflows under Option 1 were nearly identical to base conditions between January and March, resulting in no expected change in the frequency or duration of floodplain inundation under this Option.

3.1.6.3 Criterion #3. Relative degree to which the Option would increase habitat quality, quantity, accessibility, and diversity in order to enhance and sustain production (reproduction, growth, survival), abundance, and distribution; and to improve the resiliency of each of the covered species' populations to environmental change and variable hydrology.

Important stressors that affect splittail habitat quality, quantity, accessibility, and diversity (see Appendix C) are:

- Reduced juvenile rearing/adult habitat,
- Reduced spawning/larval rearing habitat, and
- Reduced food availability.

Within the planning area, splittail habitat conditions are governed by hydrodynamic conditions and the extent and quality of habitat within the planning area. Under Option 1, these conditions relative to base conditions would be affected by the conveyance configuration of Option 1 and restoration of physical habitat that could potentially be sited within Suisun Bay and Marsh and within 28% of the planning area in the north and west Delta.

The quality, quantity, diversity, and accessibility of both spawning and rearing habitat for splittail within the Delta has been reduced substantially as a result of reclamation and channelization of Delta waterways and changes in flows resulting from flood control operations. Increasing the quantity, quality, and accessibility of rearing and spawning habitat would be expected to provide the single best opportunity to promote splittail population increases.

Based on the following evaluation of Option 1 effects on applicable splittail stressors, Option 1 is expected to provide low benefits relative to habitat conditions for the splittail.

Reduced Rearing Habitat

One way to estimate the ability of Option 1 to increase the availability of splittail rearing habitat is by comparing the percentage of habitat potentially available for restoration under this Option. Approximately 28% of the Delta would be potentially available for restoration/enhancement under Option 1, which is the lowest among the four Options evaluated. However, a large proportion of the potential area would be accessible and suitable rearing habitat for splittail. Therefore, this Option would be expected to provide a low benefit to splittail in terms of increased rearing habitat. Improved access to rearing habitat can be accomplished, in part, by increasing net downstream transport. As shown above, downstream transport under Option 1 was expected to be similar to base conditions.

Reduced Spawning Habitat

High quality splittail spawning habitat occurs on floodplains and other flow-dependent habitat (Sommer et al. 1997, 2001, 2003, Harrell and Sommer 2003, Moyle et al. 2004, 2007). Access to this habitat is only available in higher flow years. In drier years, spawning occurs, but is limited to river edges and backwaters created by slightly increased flows (Moyle et al. 2004). As discussed under Criterion 2 above, peak inflows during January through March were approximately equal to base conditions, resulting in no expected change in floodplain availability under Option 1. Further, a portion of the area potentially available for restoration under Option 1 is within spawning range of splittail. Therefore, it is expected that the Option would provide low benefit to spawning habitat.

Reduced Food Availability

Habitat conditions can affect the availability and quality of splittail food. The effects of Option 1 on splittail food availability are evaluated under Criterion #4 below. As described in the Criterion #4 evaluation, Option 1 would be expected to provide a very low beneficial effect on food supply for the splittail relative to base conditions.

3.1.6.4 Criterion #4. Relative degree to which the Option would increase food quality, quantity, and accessibility (e.g., phytoplankton, zooplankton, macro-invertebrates, forage fish) to enhance production (reproduction, growth, survival) and abundance for each of the covered fish species.

The important stressor for splittail that affects food quality, quantity, and accessibility is reduced food availability (see Appendix C).

Based on the following evaluation of Option 1 effects on applicable splittail stressors, Option 1 is expected to provide very low benefits relative to food supply for the splittail. In low flow years, Option 1 would be expected to provide very low benefit for food availability to splittail and, therefore, would marginally reduce starvation mortality. In higher flow years when floodplains are inundated sufficiently, food supplies are not expected to be a major factor limiting splittail.

Reduced Food Availability

Reduced food availability can result from at least four mechanisms:

- frequency and extent of floodplain inundation,
- competition with non-native species,
- nutrient and food exports from CVP/SWP pumps and in-Delta agricultural diversions, and
- hydraulic residence time.

The degree to which food is limiting to splittail remains poorly understood (Moyle et al. 2004). It is thought that year class strength of splittail is primarily a function of frequency and duration of floodplain inundation (Sommer et al. 1997). In addition to providing spawning habitat, floodplain inundation provides larval rearing and foraging habitat. Floodplains are highly productive and beneficial seasonal habitat for juvenile splittail, salmonids and other fish (Sommer et al. 2001, Harrell and Sommer 2003) and are a source of allochthonous nutrients and organic carbon production from the terrestrial community Therefore, year-class strength may be limited to some degree by the availability of food to YOY splittail from seasonally inundated floodplains. Reduced frequency of floodplain inundation has resulted from water storage and flood protection practices by reducing the magnitude of peak flows, as well as construction of levees designed to protect floodplains from inundation. As presented above, peak Delta inflow under Option 1 would be similar to base conditions during this period (see Appendices D and H). Therefore, relative to base conditions, Option 1 would not be expected to change food availability from floodplain inundation.

With respect to the effects of non-native species on food quantity, quality, and availability to splittail, one of the major mechanisms contributing to a recent reduction in phytoplankton, zooplankton, and macroinvertebrates within the Delta has been the introduction of the overbite clam, *Corbula amurensis*. However, Kimmerer (2002) found no reduction in overall splittail population abundance after the *Corbula* invasion, unlike reductions in delta and longfin smelt. Individual growth rates of splittail have declined since the 1980s, suggesting that food supplies may have become increasingly limited (Moyle et al. 2004). *Neomysis mercedis*, a mysid shrimp known to be the primary prey species of splittail, collapsed concurrently with the invasions of a variety of lower quality non-native zooplankton species (Feyrer et al. 2003). Due to the high rate of non-native species invasions into the Delta, it is reasonable to assume that there is a causal link between these invasions, changes in the quantity and quality of prey available to splittail, and splittail abundance and year-class strength. Although the ability to manage or control non-native species within the Delta is extremely limited, one method for mitigating the adverse effects of these non-native species is through restoration and enhancement of habitat and hydrologic conditions for native species. Under Option 1, approximately 28% of the Delta would potentially be available for restoration/enhancement (Figure 1-2). This area is primarily located in the northern (e.g., Cache Slough region) and western Delta (e.g., Suisun Marsh). Both regions appear to have high habitat value for splittail and would, therefore, directly increase potential habitat for splittail rearing and foraging (Sommer et al. 1997, 2001, Moyle et al. 2004). As a result, Option 1 would be expected to have a low benefit to increasing habitat and potentially reducing the impact of non-native species on the quantity and quality of prey available to splittail. Restoration of shallow subtidal and intertidal habitats under Option 1 would also be expected to improve food supply.

In addition to exporting water, SWP/CVP diversions and over 2200 agricultural diversions throughout the Delta (Herren and Kawasaki 2001) potentially export nutrients, organic material, phytoplankton, and zooplankton that can support the base of the food web of the Delta, providing food to support the multi-aged population of splittail inhabiting the Delta (Jassby et al. 2002, POD Action Plan 2007). Because food supplies may only be limiting under drier, lower flow conditions when floodplains are not inundated, it is reasonable to assume that increasing exports of food would be important to splittail food production primarily during these periods. Particle tracking model output under the lowest water supply scenario (50% exceedance) indicates that exports of food organisms, nutrients, and organics under Option 1 are marginally lower relative to base conditions (see Appendices D and H). As a result, Option 1 provides a very low benefit to splittail by reducing exports of food during drier hydrologic conditions.

Increased residence time is expected to increase the conversion of nutrients and organics more effectively and stimulate production of phytoplankton and zooplankton. Because food supplies may only be limiting under drier, lower flow conditions when floodplains are not inundated, it is reasonable to assume that increasing residence time would be important to splittail food production primarily during these periods. Particle tracking model results indicates that there would be no difference under Option 1 relative to base conditions, indicating that this Option would not be expected to change residence time and, therefore, productivity in the Delta under drier conditions.

3.1.6.5 Criterion #5. Relative degree to which the Option would reduce the abundance of non-native competitors and predators to increase native species production (reproduction, growth, survival), abundance and distribution for each of the covered fish species.

Non-native competitors and predators are an impact mechanism for splittail predation and harvest stressors (see Appendix C).

Based on the following evaluation of Option 1 effects on applicable splittail stressors, Option 1 is expected to provide low benefits for the splittail relative to the abundance of non-native competitors and predators.

Despite the large number of non-native species that have been introduced into the Delta and Estuary, splittail have persisted (Moyle et al. 2004). Major predators of splittail are non-native species such as striped bass and centrarchids (e.g., largemouth bass and sunfish). Further, food quantity and quality may be influenced by non-native species (see above). Restoration and enhancement of habitat and natural hydrologic conditions could be implemented to decrease habitat conditions for non-native species and to the benefit of native species. Under Option 1, habitat could potentially be restored within 28% of the Delta (Figure 1-2). This entire area would be within the range of splittail and could, therefore, potentially be expected to provide a low benefit to splittail populations. There is, however, a high degree of uncertainty regarding the biological response of native species such as splittail and their prey, and non-native species of competitors and predators, to large-scale habitat modification within the Delta.

3.1.6.6 Criterion #6. Relative degree to which the Option improves ecosystem processes in the BDCP planning area to support aquatic and associated habitats.

Measurements used to assess the potential for Option 1 to improve ecosystem processes included (1) PTM modeling results for hydraulic residence time in the central Delta and (2) the proportion of the Delta expected to be suitable for restoration of aquatic subtidal and intertidal habitat. Based on the proportion of the planning area available for potential restoration under Option 1 relative to the other Options and modeling results for hydraulic residence time (see Appendix H), Option 1 would be expected to provide a very low beneficial improvement in ecosystem function relative to base conditions because although habitat restoration under Option 1 would improve ecosystem processes, hydraulic residence time would be similar to base conditions. Under Option 1, Delta channels would continue to serve as the water conveyance facilities for freshwater supplies moving from the Sacramento River across the Delta to the export facilities located in the southern Delta. Movement of large volumes of water through these channels would adversely affect hydraulic conditions within the Delta (e.g., reverse flows), salinity levels and distribution, the need for riprapped levees to reduce erosion and levee scour, and limit the opportunities for habitat enhancement. The hydraulic conditions within the Delta under these operations would also continue to result in reduced hydraulic residence times and the export of nutrients, organic carbon, phytoplankton, and zooplankton from the Delta and thereby affect aquatic food production and availability.

3.1.1.39 Criterion #7. Relative degree to which the Option can be implemented within a timeframe to meet the near-term needs of each covered fish species (post BDCP authorization).

Habitat restoration under Option 1 can be initiated immediately following authorization of the BDCP and thus could be implemented in a manner that would meet the near term needs of splittail. The implementation period for implementation of Option 1 is the same as the other Options.

3.2 PLANNING CRITERIA

3.2.1.1 Criterion #8: Relative degree to which the Option allows covered activities to be implemented in a way that meets the goals and purposes of those activities

Option 1 is anticipated to have the least ability to meet CVP/SWP water supply goals of all the Options.

Option 1 was modeled for water operations less restrictive of exports (Scenario A) and water operations more restrictive of exports (Scenario B). The ability of Option 1 to achieve the water delivery reliability and facility operation goals of the CVP/SWP is highly dependent on regulatory constraints to operations imposed by regulatory or judicial requirements (e.g., timing and quantity of water pumping to meet endangered species and water quality regulations). Although future regulatory restrictions are not known, recent court decisions applicable to Delta water management suggest that Option 1 would likely be implemented only with continued or increased operational restrictions to meet regulatory requirements (e.g., Natural Resources Defense Council versus Kempthorne). Therefore, water supply reliability under Option 1 is anticipated to be closer to the model outputs for Scenario B. Based on this assumption, Option 1 would have the least ability of the 4 Options to meet CVP/SWP water delivery goals.

Under operations and restrictions similar to existing conditions, Option 1 is expected to provide equivalent water delivery reliability as compared to current conditions (Figure 3-1). Hydrodynamic modeling results under Scenario A indicate the potential for increased long-term average CVP/SWP exports of up to 110 TAF/YR (thousand acre-feet/year), but since operations under this scenario are not likely to be authorized by current or projected regulatory restrictions, these export gains would not likely be realized. The operation of CVP/SWP Delta water project facilities under Scenario A exhibited greater flexibility primarily due to the removal the export-inflow ratio constraints as a model input. Export water quality is also expected to be similar to that under current conditions (Figure 3-2).

Under Option 1, as modeled under Scenario B, water delivery reliability and operational flexibility would be substantially reduced. Under Option 1, as modeled under Scenario B, long-term export water deliveries could be reduced by approximately 3.8 MAF/YR (million acre-feet/year). The primary cause of the reduced water delivery reliability is the restrictions on the

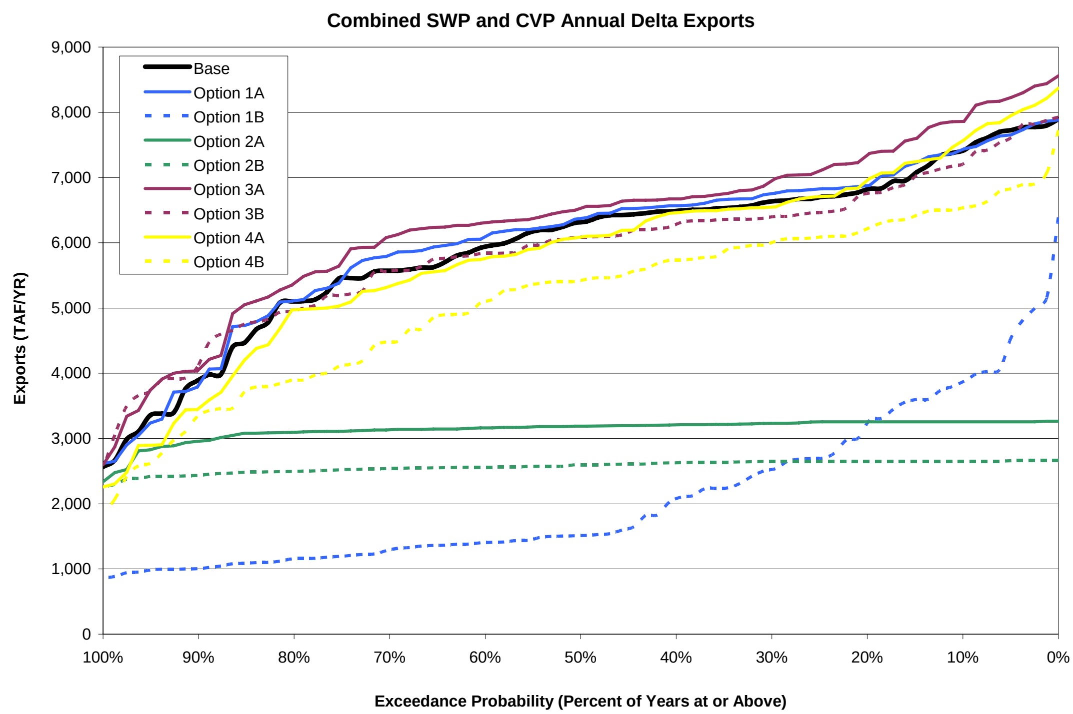

Figure 3-1. Export reliability (exceedance probability) curves for base conditions and the four Options.

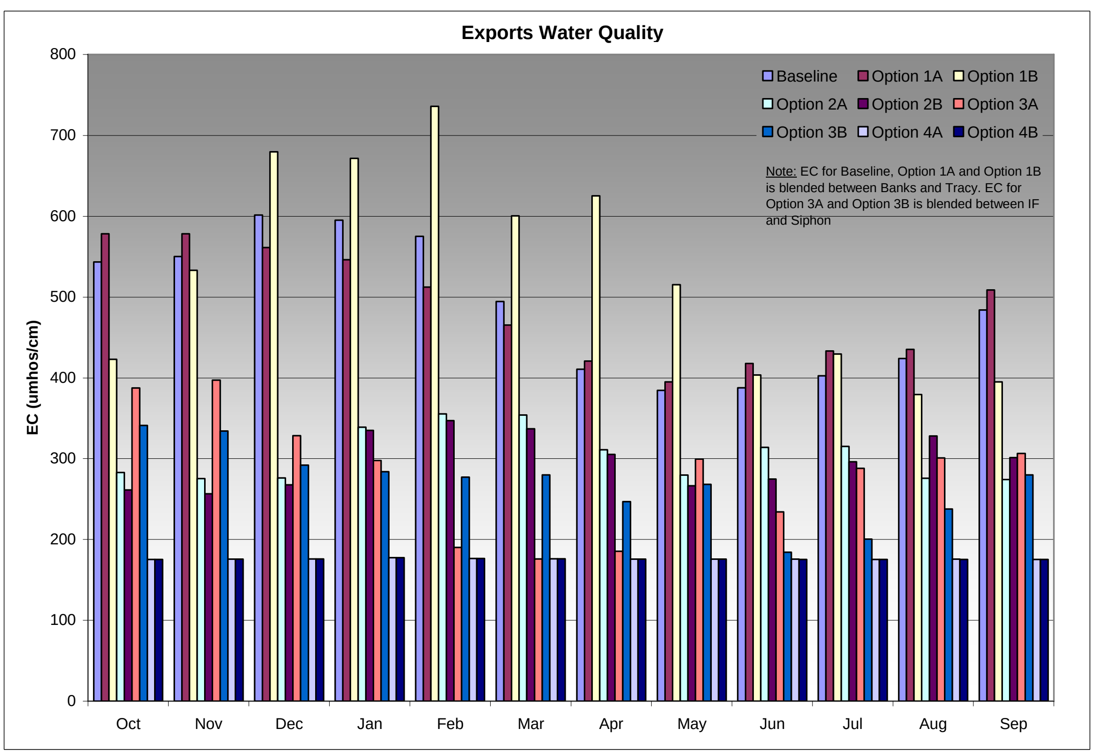

Figure 3-2. Export water quality under base conditions and the four Options.

magnitude of reverse flows in Old and Middle Rivers assumed in the model inputs. To a lesser extent, the model restrictions on reverse flows in the lower San Joaquin River (QWEST) limit the ability to export water from the south Delta. Under these conditions, deliveries to senior water right holders (CVP Water Rights and Exchange contractors) as well as CVP Refuge deliveries are not likely to be fulfilled, while deliveries to other CVP/SWP contractors (Agricultural and Municipal & Industrial) would be reduced to near zero amounts. Water quality in the south Delta is also expected to become degraded in the winter and spring as compared to current conditions as lower export rates limit the amount of Sacramento River water that is circulated in this region.

Option 1, as modeled with reduced restrictions on exports (Scenario A), would provide similar water delivery reliability to the CVP/SWP pumps as Option 3, slightly better than Option 4, and significantly better than Option 2. However, Option 1, under the more restrictive operations (Scenario B), would have the lowest CVP/SWP water delivery reliability of all Options. As described above, it is anticipated that operations under Option 1 would need to be more restricted due to regulatory constraints and, therefore, Option 1 performance would be the poorest of the 4 Options.

3.2.1.2 Criterion #9: The relative feasibility and practicability of the Option, including the ability to fund, engineer, and implement

While Option 1 may appear to be highly feasible and practicable based on its low construction cost and lack of new infrastructure, this Option has several challenges to its feasibility most importantly its questionable ability to meet planning and conservation goals within substantial ongoing input of resources.

Option 1 would use the existing Delta configuration and infrastructure to continue the long effort to achieve both species and habitat conservation and CVP/SWP water supply goals. These dual goals have not been accomplished after many years of effort under various other programs. With its relatively limited range of proactive actions, successful regulatory authorizations of Option 1 are less likely than other Options and make Option 1 less feasible as a solution for habitat conservation and water supply reliability. The more narrowly focused geographic area for habitat restoration under Option 1 limits the flexibility in choosing restoration sites; therefore, selection of the most cost-effective habitat restoration sites under Option 1 is less practicable than under the other options. The extensive permitting, engineering, and costs associated with construction of new facilities under the other Options adversely affect the feasibility and practicability compared to Option 1. Cost practicability of Option 1 is addressed in Criterion #10, below. Option 1 is estimated to be the most costly Option over the long term. For these reason, Option 1 is considered the least feasible and practicable of the four Options.

3.2.1.3 Criterion #10: Relative costs (including infrastructure, operations, and management) associated with implementing the Option

Delta Infrastructure Costs

Option 1 is expected to have the lowest infrastructure costs of the four Options. Option 1 would use existing export facilities (Jones and Banks Delta Pumping Plants) in the South Delta. No new Delta facilities are described under Option 1 in the report *Descriptions of Potential BDCP Conservation Strategy Options* (BDCP May 2007). However, there are several conceivable Delta infrastructure improvements that could be relevant to implementation of Option 1, including levee strengthening and improvements in CVP and SWP fish screens and salvage facilities.

Because levee improvements are not included as part of Option 1, it has the lowest construction costs of the four Options, but also is expected to have the highest catastrophic event impact costs, as discussed below. Possible improvements to screening and fish salvage facilities at CVP and SWP intakes are described in the DRMS Phase II report (DRMS Phase II 2007).[4] The cost of potential screening and fish salvage improvements at the Jones Pumping Plant are on the order of $290 million (2007 dollars).[5] A new fish facility at the head of Clifton Court Forebay could cost in excess of $1 billion (DRMS Phase II 2007).[6] The total construction cost to improve CVP and SWP screening and salvage facilities could be on the order of $1.3 billion.

Delta Conveyance Disruption Costs

While Option 1 entails the lowest construction cost because no new facilities are currently proposed, it would also be the most vulnerable to flood and seismic events, which have a high probability of causing significant damage to levee infrastructure and disruption of water exports. Given existing Delta conveyance facilities, seismic events pose the greatest risk to Delta water exports.[7] Analysis done for DRMS Phase 1 (DRMS Phase I Report June 2007) indicated that a seismic event resulting in the simultaneous flooding to ten or more islands could shut down water exports for up to 10 months. The probability of such an event occurring in the next 25 years was estimated to be between 50% and 60%. Flooding of 20 or more islands could shut down water exports for up to 2 years. The probability of such an event occurring in the next 25 years was estimated to be between 30% and 40%. DRMS estimated the ten-island scenario would reduce Delta water exports during the repair and recovery period by 0.7 to 2.5 MAF/YR. For the case of 20 or more flooded islands, DRMS estimated that exports from the Delta would fall by between 6.3 and 9.3 MAF/YR during the repair and recovery period. State-wide economic impacts from such events were estimated to range between $10 and $50 billion.

Export Water Quality Costs

Based on BDCP hydrodynamic modeling results, Option 1 would provide only a negligible improvement in export water quality relative to existing conditions.[8] Option 1, therefore, would not provide the large savings in municipal water treatment costs expected under Options 2, 3,

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[4] Fish screen improvements and costs are discussed in Section 15 of the DRMS Phase II report.

[5] The estimate is based on improvements described in a 1998 report prepared by the United States Bureau of Reclamation's (USBR's) Tracy Fish Facility Team (USBR November 1998). USBR, *A Proposed Technology Facility to Support Improvement and/or Replacement of Fish Salvage Facilities at Tracy and Other Large Fish Screening Sites in the Sacramento-San Joaquin Delta, California*, prepared by the Tracy Fish Facility Team, November 18, 1998.

[6] The DRMS Phase II report is the source of this estimate. Costs for Clifton Court Forebay improvements are very preliminary and DRMS noted that technically feasible facilities have yet to be determined. DWR investigations cited by DRMS found high unit costs, ranging between $50,000 and $90,000/cfs, due to extensive changes to the fish collection system, scale of construction, and geotechnical challenges posed by south Delta soils.

[7] Flood events had much lesser impacts on Delta exports because high water flows prevented significant saltwater intrusion from occurring in the southern part of the Delta.

[8] This finding is based on CALSIM modeling result summarized in BDCP-ModelingResults_082707.ppt.

and 4. Under the other Options, these savings could be between $1.0 and $2.5 billion over the next 25 years. Relative to the other three Options, Option 1 is, therefore, expected to result in the highest export water quality costs.

Habitat Restoration Costs

The evaluation assumes that the overall amount of habitat restoration would be roughly the same across the four Options although the locations could differ. Therefore, cost estimates for habitat restoration that were developed with currently available information do not distinguish Option 1 from the other three Options. While the unit costs of restoration may vary to some degree according to the range and location of the restoration activity, sufficient information on unit restoration cost differentials is not available at this time to distinguish among the four Options. Thus, habitat restoration costs are not treated as a significant distinguishing feature among the four Options.

3.3 FLEXIBILITY/DURABILITY/SUSTAINABILITY CRITERIA

3.3.1.1 Criterion #11: Relative degree to which the Option will be able to withstand the effects of climate change (e.g., sea level rise and changes in runoff), variable hydrology, seismic events, subsidence of Delta islands, and other large-scale changes to the Delta

Among the four Options, Option 1 is expected to have the least ability to withstand large-scale changes to the Delta that would adversely affect species conservation and covered activities. The extent of levees supporting Option 1 conveyance that are subject to breaching or overtopping during flood events is greater than under the other Options because all (Option 4) or portions (Options 2 and 3) of conveyance infrastructure would be engineered to withstand floods. The probability of flood-induced levee failures is expected to increase in the future based on climate change-induced sea level rise and river hydrology change (DRMS Draft Stage I Report 2007). Option 1 would have to incorporate substantial financial investments in levee improvements to approach the durability levels that could be achieved by other Options.

Risk to Habitat Restoration Actions

Under Option 1, habitat restoration would be focused in the north Delta and Suisun Marsh and is expected to have the narrowest geographic distribution among the Options. A levee failure at or near restoration sites may have a disproportionate adverse effect under Option 1 because restoration sites are geographically more concentrated than in other Options. Similarly, Option 1 would provide less flexibility to adjust flow operations in restored habitat in the event of levee failure(s) caused by flooding or seismic events than would be provided by the other Options because of the more localized habitat restoration sites. All Options, however, include restoration outside the planning area at Suisun Marsh, an area that likely is less subject to habitat loss from seismic or flood events than much of the planning area.

Protecting physical habitat restoration against the effects of sea level rise requires that restoration sites be located at higher elevations (sites in the Delta with less subsidence) and along elevation gradients that include an ecotone between tidal and upland habitat. Restoration sites in such locations would allow the gradual upward elevation shift of all tidal habitats in response to sea level rise over time. The limited geographic focus of habitat restoration under

Option 1 relative to other Options reduces the number and extent of sites with such elevation characteristics available for habitat restoration in the Delta and, therefore, restoration would be less durable.

Risk to Water Supply Infrastructure

Option 1 would provide the least protection of the four Options to water supply facilities from seismic or flood events and from the ongoing effects of sea level rise. Levee failure from a seismic event during low Delta inflow/outflow periods (seasonally in all years and most of year in dry and critical dry years) poses the greatest risk to water export facilities in the south Delta; Option 1 provides no new protection to these facilities from levee failure and the subsequent expected intrusion of saline water up to the pumping facilities (DRMS Draft Stage I Report 2007). The other Options provide new protections to water conveyance facilities through operable gates, improved levees, and a peripheral aqueduct. These protections are not provided by Option 1 and, therefore, make Option 1 less durable and less sustainable for water supply than the other options.

3.3.1.2 *Criterion #12: Relative degree to which the Option could improve ecosystem processes that support the long-term needs of each of the covered species and their habitats with minimal future input of resources*

Of the 4 Options, Option 1 appears to be the least sustainable without an ongoing input of resources for the following reasons:

1. Depending on location, existing and restored habitat that supports covered species may be influenced by Delta pumping to a greater extent than under the other three Options. Therefore, Option 1 would likely face continued seasonal pumping restrictions and would require continued funding of water acquisitions for environmental purposes.

2. Habitat management and restoration under Option 1 would be more limited than under the other three Options and thus could prevent or slow the recovery of covered species that are dependent on improved in-Delta habitat conditions.

3. Option 1 likely would continue to entrain fish, including covered species, at a higher rate than under all other Options and, therefore, would require continual funding for trucking, hauling, and release of fish.

4. Option 1 would have greater ongoing costs associated with managing for harmful invasive species than Options 2, 3, or 4. This is because Option 1 provides the least opportunity to use variable salinity regimes in the Delta as a tool to control invasive species. The more stable hydrological conditions under Option 1 limit the ability to adaptively manage the hydrologic regime for the control of invasive species and, therefore, require that repeated and likely more costly on-site measures be taken to achieve similar control.

3.3.1.3 Criterion #13: Relative degree to which the Option can be adapted to address needs of covered fish species over time

Option 1 is expected to be the least flexible and adaptable among the Options to address possible future conservation of the covered fish species.

Relative to the other Options, a substantially smaller percentage of land area within the Delta is available for restoring high function habitat under Option 1. Therefore, the ability to increase the extent of restored habitat for covered species in the future would be constrained to fewer possible sites. Because of the geographic limitations for habitat restoration to the west and north Delta and Suisun Marsh under Option 1, there is less adaptability than other Options to restore habitat in other geographic portions of the Delta that may be identified in the future as important to the conservation of covered species.

The flexibility to adjust Delta hydrology is substantially constrained by the need to maintain through-Delta flow conveyance to the south Delta pumping facilities. Consequently, additional infrastructure would be required to manage flow patterns to adaptively improve ecological process and benefit covered species while maintaining conveyance through the Delta to the water export facilities.

3.3.1.4 Criterion #14: Relative degree of reversibility of the Option once implemented

Option 1 is the most reversible among the Options because no new conveyance infrastructure would be constructed. Consequently, no removal or demolition of facilities would be required. Public acceptance would likely be high because there would be no physical effects on infrastructure. Costs to reverse the Option are expected to be minimal.

3.4 OTHER RESOURCES IMPACTS CRITERIA

3.4.1.1 Criterion #15: Relative degree to which the Option avoids impacts on the distribution and abundance of other native species in the BDCP planning area

If Option 1 were implemented with flow requirements similar to current conditions, then the probability of adverse impacts on other native aquatic species within the Delta under Option 1 is expected to be similar to existing conditions and greater than under the other Options.

Implementation of Option 1 is not expected to result in changes to the distribution and abundance of other native aquatic species within the Delta relative to changes occurring under existing Delta conditions. Because other native fishes are entrained at the SWP/CVP export facilities (DFG file data), reduced exports compared to current conditions that could be provided for within the range of possible operations could be beneficial for native aquatic species as a result of reducing the risk for their entrainment. Minor adverse impacts on native aquatic species could result from increased entrainment potential and reduced food production (see evaluation of biological criteria) during periods that exports exceed current conditions. These impacts are expected to be minor because the proportionate potential increase in exports from current conditions is small (see Figure 3-1).

Under Options 2, 3, and 4, the volumes of water exported from the south Delta are substantially less than under Option 1 and current conditions. Consequently, the likelihood for entrainment of other native aquatic species in the south Delta would be greater under Option 1 than under the other Options. Option 1, however, would result in less entrainment of fish from the central Delta than Options 2 and 3 where Options 2 and 3 result in increased reverse flows in Middle River.

The level of adverse impacts on terrestrial native species within the Delta are expected to be the lowest under Option 1 relative to the other options because Option 1 does not include new facility construction that could remove existing habitat or disturb wildlife.

3.4.1.2 Criterion #16: Relative degree to which the Option avoids impacts on the human environment

The types of adverse impacts as defined under the California Environmental Quality Action (CEQA) and the National Environmental Protection Agency (NEPA) on the human environment that could be associated with Option 1 are described in this section.[9] Potential impacts described here for Option 1 would not necessarily be significant or could be reduced to less-than-significant levels through CEQA/NEPA mitigation measures.

As defined for this evaluation, Option 1 would not require the construction of new facilities or any other type of ground-disturbing activities. Consequently, Option 1 is expected to incur no or minimal impacts on the following CEQA/NEPA impact categories:

- Geology/soils,
- Cultural resources,
- Air quality,
- Noise,
- Aesthetics,
- Hazards/hazardous materials,
- Transportation/traffic,
- Land use/planning,
- Recreation,
- Utilities and public services,

[9] The evaluation of Criterion #16 focuses on the likely range of adverse direct and indirect impacts of the Options in the planning area and not the indirect impacts to water quality and water supply reliability and in the service areas. These issues in the service areas are addressed in Criteria #8 and #11. Although Option 1 would have the fewest direct impacts, it is expected to result in the lowest export water quality with attendant adverse effects on treatment costs, agricultural production, and human health. Option 1 is also the most vulnerable among the Options to future disruption of water supply to service areas as a result of catastrophic events.

- Energy usage, and
- Environmental justice.

Because Options 2 through 4 would involve construction of new facilities and ground-disturbing activities, Option 1 would have the lowest impact in the planning area of the four Options on the resources listed above.

Water Quality/Hydrology

The quality of water, as measured by electrical conductivity (EC), that would be exported from the SWP/CVP facilities under Option 1 would generally be expected, within the range of modeled operations, to be similar to current conditions. Option 1 would provide the lowest quality of exported water among the Options (see Figure 3-2). Opportunistic operations under Option 1 that export more water during peak flow periods and less during low flow periods to achieve water supply goals, however, could improve the quality of exported water. Relative to the other Options, lower quality water that is exported under Option 1 would be expected to incur higher water treatment costs to meet water quality standards and needs for municipal, agricultural, and residential uses in service areas (see discussion under Criteria #10).

Within the range of Option 1 operations that would likely meet water supply objectives, water quality within the Delta is expected to be similar to current conditions (see Figures 3-3 and 3-4). Within the Sacramento River Delta (as measured at Emmaton on Sherman Island) and the range of modeled operations, water quality under Option 1 would generally be expected to be lower than Option 2 during fall and winter months but higher than Option 2 during late spring and summer; generally higher than Option 3 in all months; and generally higher than Option 4 from February through August and lower than Option 4 from September through January. Water quality would be expected to be somewhat lower in the east Delta under Option 1 than under Options 2 and 3 because those Options will prevent or reduce the flow of lower quality San Joaquin River water entering the east Delta.

Within the San Joaquin River Delta (as measured on Old River at State Highway 4) and the range of modeled operations, water quality under Option 1 would generally be expected to be higher than the other Options in all but the fall months. Water quality would be higher during these periods because lower quality San Joaquin River water would not be exported under those Options and would be allowed to discharge into the south central Delta.

Because no new construction would occur, Option 1, unlike the other Options, would not result in any temporary localized erosion and runoff of sediments into Delta waters that could temporarily degrade water quality.

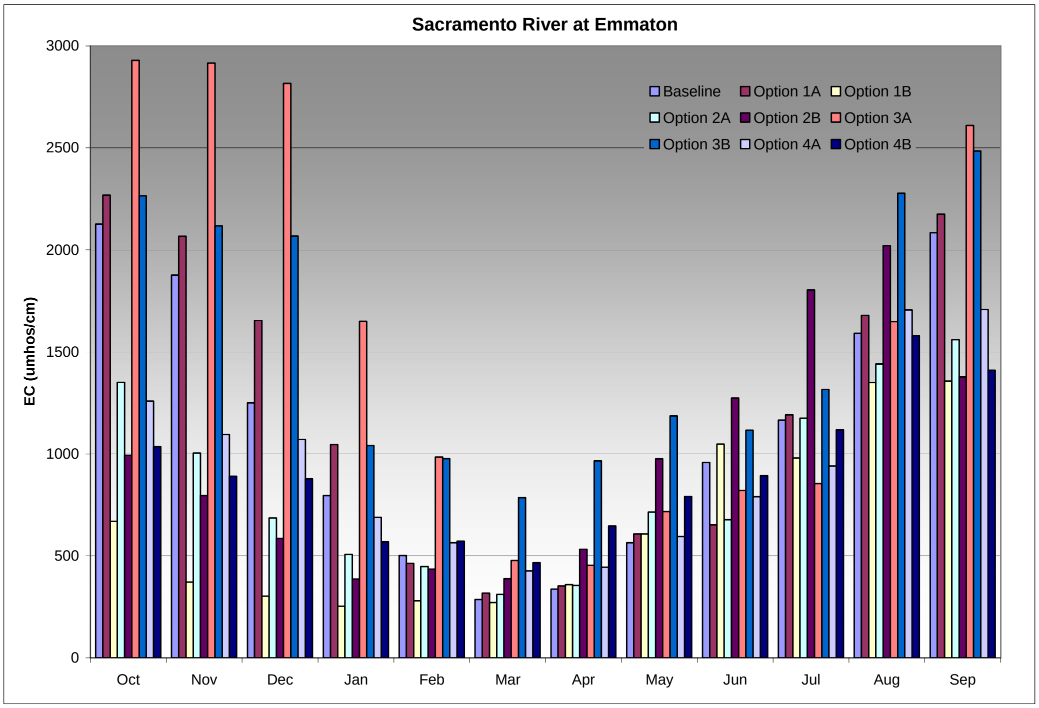

Figure 3-3. Predicted Sacramento River water quality at Emmaton (Sherman Island) expressed as electrical conductivity (EC) for each of the Options and current conditions.

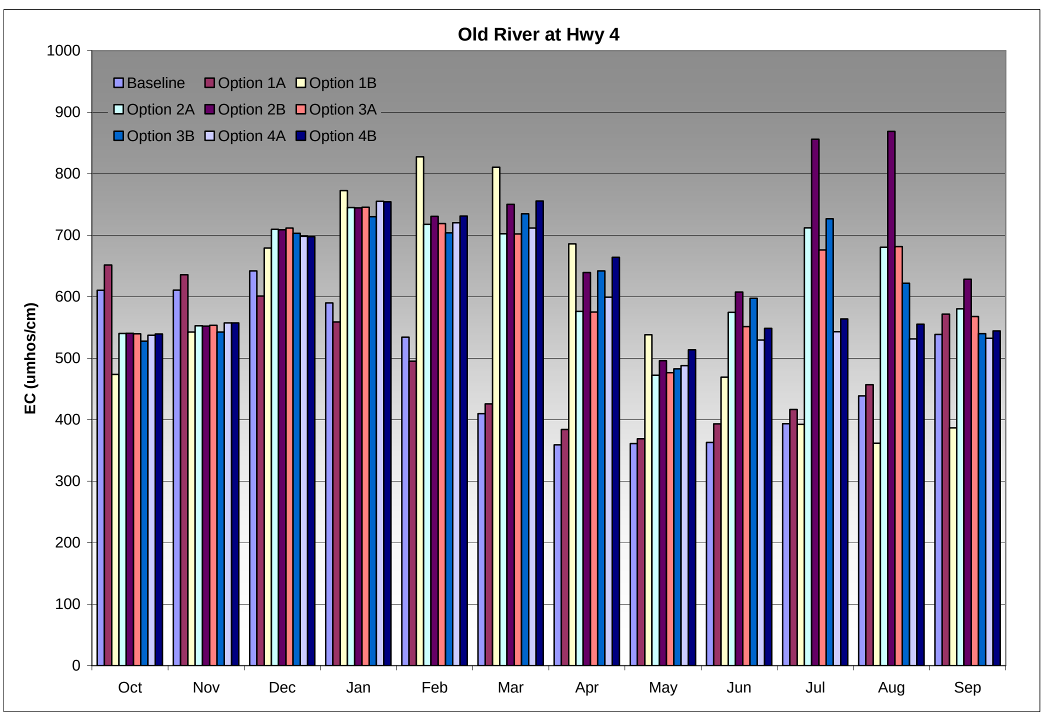

Figure 3-4. Predicted San Joaquin River water quality at the State Highway 4 crossing of Old River expressed as electrical conductivity (EC) for each of the Options and current conditions.

Agricultural Resources

Option 1 is expected to have the least impact among the Options on agricultural lands in the Delta for the following reasons:

- Existing farmed lands would not be removed from production for facility construction as would occur under Options 3 and 4.
- Water quality would remain similar to current conditions and water quality under the other Options would be lower in the south central Delta. Farming practices or production could be affected.

3.4.1.3 *Criterion #17: Relative degree of risk of the Option causing impacts on sensitive species and habitats in areas outside of the BDCP planning area*

Adverse or beneficial effects on native species and habitats outside the planning area downstream in Suisun Bay and Marsh and upstream in the Sacramento River and its major tributaries could result from changes in flow regimes downstream of the Delta. The potential for adverse effects downstream of the Delta are indicated by differences in Delta outflow among the Options, and the potential for adverse effects in the Sacramento River and its tributaries are indicated by differences in end-of-September reservoir storage volumes, which is a measure of the capacity of reservoirs to provide for cold water releases to sustain water temperatures within ranges favored by native aquatic species.

Based on model outputs, average annual outflow for Options and base conditions are estimated to be:

- Base conditions – 14,991 cfs
- Option 1 – 14,890 cfs
- Option 2 – similar to Option 1 (14,799 cfs – preliminary model output with pump facility)
- Option 3 – 20,289 cfs
- Option 4 – 20,996 cfs

Based on preliminary analyses, the potential for beneficial effects on aquatic species and habitats downstream of the planning area appear to be less under Option 1 than under Options 3 and 4 because the potential average annual Delta outflows supported under Option 1 are anticipated to be lower than the potential outflows under Options 3 and 4 under a range of hydrodynamic model scenarios (see Appendices D-G). Option 1 would generally provide for Delta outflows similar to current conditions. Option 1 outflows would be similar to Option 2. Opportunistic operations under Option 1 that export more water during peak flow periods and less during low flow periods to achieve water supply goals could allow for greater Delta outflow during low-flow months that could result in benefits to native aquatic species. Modeled Delta outflows, however, under Option 1 in different water-year types, with CVP/SWP exports similar to current conditions, do not appreciably differ from current conditions and would not be expected to have a measurable effect on sensitive species and habitats outside of the Delta. In the biologically important months of March and April, Option 1 provides greater Delta outflow (2%-6% less than base in below normal years) than Options 3 and 4 (3%-12% less than base in below normal years) because Options 3 and 4 would distribute outflows more evenly through the year.

Under the range of modeled operations, Option 1 is not expected to affect upstream river water temperature conditions relative to current conditions and could provide for cooler releases from Oroville Reservoir compared to current conditions during critical water years. Based on reservoir storage volumes at the end of September, the ability to provide for cold water releases downstream of Shasta, Folsom, and Oroville Reservoirs under Option 1 would be expected to be similar to Options 2, 3, and 4 in most water-year types. During critical water years, Shasta Reservoir storage volume would be similar to Option 2, but greater than under Options 3 and 4; Folsom Reservoir storage volume would be similar to Options 2 and 3, but greater than Option 4; Oroville Reservoir storage volume would be similar to Options 2 and 3 and greater than Option 4 during dry years; and during critical years, Oroville Reservoir storage volume would be lower than under Options 2 and 3, but higher than under Option 4.

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